

May, 1942

Volume 41, No. 5

Metal Progress

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Cover photo is a 20-ft. scroll case in a turbine at Norris Dam, T.V.A. The design is by Isabelle Szabo, winner of a competition at Cleveland Art School.

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Stress cracking is overcome in the above refrigerator door pan by mounting both the draw and trim dies in the same press, cutting to seconds the lapsed time between draw and trim.

How to Prevent Stress Cracking

Losses due to "spontaneous" cracking of severely drawn, or cold worked mild steel and iron are troublesome, particularly now when maximum war production demands economy of steel and the greatest possible number of usable parts made in the shortest possible time.

Cracking, or splitting, occurs after the draw operation, often when the parts are finished and placed in stock. The causes of failure are the severe strains in the metal and age hardening resulting from cold working. Work hardening in corner draws has been known to increase hardness from Rockwell B-40 in the blank to Rockwell B-81 in one particular type of pan.

To prevent stress cracking, start with a steel

suitable for the job. Avoid extreme changes of temperature, such as storage of parts in cold areas. If equipment is available, relieve stresses by annealing soon after the drawing operation, or trim immediately after drawing before the metal age-hardens and loses much of its ductility. Cracking has been eliminated by reducing the lapsed time between draw and trim from hours to seconds. In some instances draw dies and trim dies can be assembled in the same press thereby cutting lapsed time to the minimum by permitting a draw and a trim at each press stroke.

Inland metallurgists have helped many manufacturers use steel economically to speed up war production. They are ready to help you.

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America Self-Sufficient in Manganese

MANGANESE, being an essential ingredient in *all* steel, has been given much attention in the columns of METAL PROGRESS during the last year; statements concerning the supply and current needs, and articles about its conservation, have been appearing with regularity. Older readers of this magazine will also remember editorials dating back to 1930 about the desirability of stock-piling foreign manganese, or developing means of production from our vast tonnages of low grade ores. No one seemed much interested except the U. S. Bureau of Mines; up to the limit of its meager appropriations its research metallurgists studied a number of American ores and worked out laboratory processes for concentration, leaching or smelting that looked interesting. Likewise a lobbying group called "American Manganese Producers' Association" has promised self-sufficiency in return for tariff protection; however, since these men rely upon scattered prospects and foxholes in the Southern Appalachians, post-War production of 35% ore has never gone above 40,000 tons in a year—a mere drop in the bucket.

So here we are, in the year 1942, with requirements at the highest level in history, and a realization that all our existing stocks came from foreign sources, such as Russia and India. With things going as they are, we can't be very

sure of anything except the resources of our own hemisphere. We can't rest until we are providing ourselves with 500,000 tons of ore yearly from our own United States, and since we can't hope to approach this, even for a single year, from our scattered veinlets of high grade, it is absolutely essential that something vigorous be done in the development of the low grade deposits.

It will be good news to American metallurgists that the War Production Board *has* done something vigorous, and the program is in the hands of responsible and successful concerns, capable of solving the technical problems involved. By 1944 (cer-

tainly by Jan. 1, 1945) we will be producing at a 600,000-ton rate, and even if *all* shipping from the Orient and Africa were stopped tomorrow, our present stock-piles can be made to carry us over the interim, and not restrict the output of our steel and iron industry.

Here is where American manganese is coming from:

Montana: A brief account of the production from Montana mines has been given in "Critical Points" in August 1941. Carbonate ores from Butte, containing 25% manganese, are being concentrated and the fines sintered into 57% Mn nodules at better than 80,000 tons per year. By extensions to the flotation plant the 1943 production will be 140,000 short tons per year of this very high grade ferro ore.

Nevada: Six months ago a contract was awarded M. A. Hanna Co., important factor in the Cleveland iron ore and coal trade, to develop a Nevada deposit near Las Vegas having a six-year supply of proven ore, half of it from open pits. The mineral is psilomelane (hydrated MnO_2) and is soluble in dilute SO_2 solutions. Fortunately the calcium in this ore already exists as sulphate, so great quantities of sulphur will not be locked up in an undesirable precipitate; the soluble MnSO_4 is crystallized out of the filtered solution in multiple effect evapo-

rators and the SO_2 regenerated by heating the sulphate to produce MnO_2 nodules. 110,000 short tons of 60% ore will be made here in 1943 and every year thereafter, until 1949.

Minnesota: War Production Board is negotiating with Anaconda Copper Mining Co. to build a \$20,000,000 plant in Minnesota to leach manganese out of the "black ores" of the Cuyuna iron range. At least 12,000,000 tons of this ore containing 12% manganese or more is in proven reserves; it will be treated much like the Nevada ore except that a preliminary leach with dilute H_2SO_4 will take the Mn^{++} oxides into solution before adding SO_2 gas for the Mn^+ . Since so much more ore is available here than in Nevada, the plant will have double the capacity, and 225,000 tons of 60% nodules will be coming from Minnesota in 1944 and yearly thereafter.

South Dakota: Our real "ace in the hole", however, is the Chamberlain shales in South Dakota, one of the world's largest deposits, containing at least 100,000,000 tons of metallic manganese! 70% of the values are in concretions $\frac{1}{4}$ in. in size and larger scattered through

the shale. About 100 tons of shale will have to be handled to get a ton of manganese metal, so it is a job for excavators. War Production Board is therefore arranging with three concerns experienced in large scale mining and dirt moving to install and operate the necessary equipment. Treatment fortunately is easy: Rough crushing frees the larger hard concretions from the soft shale and they can be screened out; the rest goes through a kiln for partial drying and the rock when slaked with water disintegrates into a fine mud from which the smaller concretions (which remain unaffected) can be separated by ordinary water concentration equipment. Metallurgical treatment of this carbonate, containing 18% Mn and 11% Fe, is not yet decided; several schemes have been proposed but for the present it will be stock-piled and, if necessary, smelted by dilution with the high grade oxide nodules from Montana, Nevada and Minnesota. Equivalent of 100,000 tons of ferro-grade ore will be coming from these inexhaustible shale beds, yearly, starting in 1944.

Other States: There remains a number of smaller mills recommended by the Bureau of Mines and operating on scattered deposits each by appropriate processes worked out by the Bureau. War Production Board has already authorized mills at Batesville (Ark.), Delta (Utah), Phillipsburg (Mont.), Battle Mountain (Nev.), Cartersville (Ga.) and Elizabethton (Tenn.). Ore deposits in these regions have as yet no proven large reserves; nevertheless, when added to that of the old mines now in production, they may be expected to add another 75,000 tons of 60% concentrate by 1945.

To recapitulate, plans for 1945 production comprise (in short tons of ferro-grade ore)

Montana	140,000 tons
Nevada	110,000
Minnesota	225,000
South Dakota	100,000
Other States	75,000
Total	650,000 tons

This, plus reasonably expected imports, will give us the tonnage necessary for our steel industry, operating at capacity, year after year, indefinitely.

Try to laugh that off, Messrs. Hitler, Hirohito, and Mussolini!

Manganese Concentrates Are Dried and Nodulized in Long Rotary Kiln (Photo by Rittase)



Conservation of Manganese by Steel Makers

A REPORT on Emergency Conservation of Manganese (printed in METAL PROGRESS in December 1941) was presented to the Office of Production Management by the National Academy of Science's Advisory Committee on Metals and Minerals. In order to develop a more specific set of recommendations and to obtain the support of the steel industry and its customers in the suggested manganese conservation measure, this Committee requested the cooperation of the American Iron and Steel Institute. As a result, the Institute appointed an informal committee of six under the chairmanship of C. H. HERTY, Jr., to study the possibilities. This committee has reported as follows:

Overall Requirements

The use of a manganese in any steel product is governed primarily by specifications set by the producers, designed to contribute to the physical properties of the finished steel or to enhance the surface quality obtained in rolling, forging or casting. Equally important are the specifications set by consumers, specifying manganese ranges for certain physical properties or heat treatment processes.

In many cases specifications in the two classes duplicate one another; in other cases

they are independent of one another. For example, the manganese ranges in specifications for plates may be identical with what would be set by steel producers were there no consumer specifications. On the other hand, consumer specifications for sheet steel and strip steel are rare, and the manganese content is determined almost entirely by the steel maker's experience as to rolling performance and desired physical properties.

The quantity of ferromanganese consumed by various steel mill products, estimated from 1940 production records, is given in the table at top of the

next page.

Since the manganese limits in bars, rails, wheels, axles and forgings are usually set by the consumer, and the limits in sheets, strip, tinplate, shapes, piling, rods and wire are largely set by the steel maker, it is fair to conclude that the responsibility for manganese conservation is the mutual problem of producer and consumer. Among the problems to be solved by steel producers is the determination of the limits to which reduction of the manganese content of steel can be carried without impairing surface quality, production rates or both. It should be carefully noted that a large number of small reductions, if applied generally, will result in a large saving of manganese.

For the purposes of this report steel products can be divided into three classes, namely: Class A, products in which the manganese content of steel can be reduced with little or no effect on the production rate or quality of the steel; Class B, products in which the manganese content may be reduced with a probable adverse effect on both production and quality; and Class C, products in which, if the manganese contents were reduced, definite effects on both the production rate and quality of the steel would be expected.

Estimated 1940 Consumption of Ferromanganese by Products

PRODUCT	APPROXIMATE INGOT EQUIVALENT, NET TONS	FERROMANGANESE CONSUMED		
		TOTAL, POUNDS	POUNDS PER TON OF INGOTS	% OF TOTAL
Bars	10,800,000	288,700,000	26.6	29.3
Sheets and strip	19,430,000	193,700,000	10.0	19.8
Shapes and piling	6,550,000	107,000,000	16.3	11.0
Semifinished products	5,650,000	81,200,000	14.4	8.3
Plates	5,950,000	74,400,000	12.5	7.6
Rods and wire	5,990,000	62,100,000	10.4	6.3
Tinplate	4,990,000	52,000,000	10.5	5.3
Rails	2,310,000	49,600,000	21.5	5.1
Pipe	3,730,000	43,050,000	11.5	4.4
Wheels, axles, forgings	1,530,000	28,700,000	18.8	2.9
Total	66,930,000	980,450,000	Av. 14.8	100.0

Specific Recommendations

Shell Steel is a bar product falling into Class A above, that is, one in which manganese can probably be conserved without endangering production or quality.

At present [Nov. 6, 1941] the steel compositions most commonly specified for American shells are WD-X1335, WD-X1340, and WD-X1345 all of which require 1.35 to 1.65% Mn.

In order to meet those specifications about 43 lb. of 80% ferromanganese per ton of ingots must be used—about three times the average requirement for all steels made in this country. This represents a potential serious drain on existing stocks of ferro-alloy or ore, a drain which is directly proportional to the tonnage of shell steel which will be required. (It should be noted that the rather large proportion of the ingot which is converted into mill scrap, forge shop scrap and machine shop scrap is of no real value subsequently as a source of manganese because most of the manganese is lost in remelting.)

The high manganese in these WD steels has two functions. The first is to convert most of the sulphur to manganese sulphide and thus improve the rolling and forging properties of the steel. For that purpose alone the specified manganese is far too high. In this connection it is important to note that the tendency of high sulphur steels to break in rolling or forging depends to a great extent upon the carbon content, and the tendency is much more apparent in steels containing approximately 0.20% carbon than steels with 0.40%. Steels containing from 0.35 to 0.50% carbon and 0.075 to 0.15% sulphur can be, and large tonnages have been,

rolled or forged satisfactorily with 1.00 to 1.30%, or even 0.80 to 1.10% manganese.

The second function of manganese in the WD series of steels is that of a hardener. The hardness, yield point and tensile strength of such steels are increased in the air-cooled or oil-quenched conditions. Until recently the hardness requirements of high explosive shell forgings which had been

cooled naturally, or with an air blast, were based on yield points of 55,000, 45,000, and 40,000 psi. It is relatively simple to obtain a yield point of 45,000 psi. in a steel similar to WD-X1340 but with 1.00 to 1.30% manganese or perhaps even lower.

The yield point requirement for all types of shells made from these steels has recently been increased to 60,000 psi. We understand that as soon as heat treating facilities are available, high explosive shells will be specified to even higher physical properties which will be obtained by oil quenching and drawing. Such a revision in specifications will make possible the use of a normal manganese steel with either normal sulphur or sulphur slightly higher than normal. This would, of course, save manganese, because by heat treatment, higher physical properties can be obtained with a given manganese content than can be obtained by air cooling. Actual heat tests have shown that desired physical properties can be met with 0.35% cold drawn steels containing 1.00 to 1.30% Mn.

The high sulphur in shell steels being currently manufactured requires some manganese to overcome hot-shortness. It may reasonably be assumed that the manganese which combines with sulphur to form manganese sulphide does not contribute to the hardness or yield point of the steel. Sulphur is added to steel to enhance its machinability but many machine tools used for large calibers will not run fast enough to take full advantage of this extra machinability. The cutting tool is also a factor. Provided equipment is sufficiently rigid, the surface speeds regularly used with cemented carbide tools on low sulphur steels are higher than with high speed steel tools on high sulphur steels.

Commercial High-Manganese Steels fall into Classes A and B as defined above. Standard steel compositions A1330, A1335 and A1340 have 1.60 to 1.90% Mn and 0.04% max. S. It is the opinion of the Committee that there are many applications where steels of lower manganese content would serve the purpose satisfactorily and that the use of such steels could be encouraged by adding suitable standard specifications and giving publicity to them. Such specifications might be similar to General Motors compositions Y1335 and Y1340, which call for 1.35 to 1.65% manganese with 0.05% max. sulphur.*

In the sulphurized high manganese steels we now have A.I.S.I. composition C1137 containing 1.35 to 1.65% Mn and 0.08 to 0.13% S. Medium carbon steels of lower manganese content are provided in A.I.S.I. C1140 (0.60 to 0.90% Mn) and C1145 (0.70 to 1.00% Mn). These, however, contain only 0.04 to 0.07% S. General Motors composition 1135 contains 0.70 to 1.00% Mn and 0.075 to 0.150% S, while General Motors composition 1145 has 0.75 to 1.05% Mn and 0.080 to 0.160% S. Because of the carbon content, these grades roll reasonably well with the stated contents of manganese. They are suitable for numerous applications in which A1335 or A1340 or C1137 are used. Where somewhat greater hardness or hardenability is required, it is the opinion of the Committee that there is a field for medium carbon sulphurized steels containing 1.00 to 1.30% manganese.†

Steel Bars and Forging Billets, (Carbon and Alloy)—This general classification absorbed 29.3% of the manganese in 1940. In attacking the problem of manganese conservation in these grades there are three items to be considered:

1. In the past the consumer-producer relationships have been of paramount importance in developing proper specifications, and become even more important in determining modifications in manganese content which will permit the manufacture of a satisfactory product.

2. With proper consideration of the whole problem of manganese conservation it is evident that the most logical substitute for manganese in these grades is carbon.

*EDITOR'S NOTES — These recommendations have apparently resulted in the establishment on Jan. 21, 1942, of C1036 steel, for basic openhearth bars, containing 0.32 to 0.39% C, 1.20 to 1.50% Mn (low enough to escape classification as an "alloy steel" in A. I. S. I. parlance), 0.04% max. P, and 0.05% max. S. See Data Sheet, METAL PROGRESS, March 1942, page 345.

†The present standard list contains sulphurized steels of this sort with carbons up to 0.20% max.

Scrap is Urgently Needed!

★ ★ ★

1. WRECK UNUSED EQUIPMENT.
2. COLLECT and SEGREGATE all WASTE MATERIAL.
3. DISPOSE PROMPTLY to NEAREST SCRAP DEALER.

★ ★ ★

Be a Crusader in the
WAR ON WASTE!

3. If it were economic for consumers to use lower manganese steels than their current practice for any given product, there would undoubtedly be a real decrease in the manganese requirements, for these grades consume almost one-third of the total.

It is considered advisable to divide bars into two main classes:

1. Bars subsequently heat treated.
 - a. Alloy steel
 - b. Carbon steel
2. Commercial bars.

The tonnage is approximately equally divided between the two. Item 1a would generally fall into Class C, whereas Item 1b would fall largely into Class B. In dealing with these grades there are two possible attacks:

The first is changing from a fine-grained to a coarse-grained steel, reducing manganese with little or no change in the carbon content. This would affect:

1. Surface and segregation. There would probably be (a) more surface preparation required and somewhat higher rejections for surface defects; (b) the possibility of slower production on blooming mills where double heating might be required; and (c) somewhat higher rejections for segregation in top billets.
2. In forging the bars there might be increased rejections through trimming cracks.
3. It would often be necessary to revise heat treatment cycles.
4. There would probably be a slight change in ductility properties, but a somewhat better machinability.

The second method of dealing with forging billets is to lower the manganese and increase the carbon without interfering with the grain size characteristics. This change would involve the possibility of a change in the heat treating cycle and some lowering of impact properties.

In the higher carbon ranges there would probably also be a decrease in machinability.

In the higher manganese steels containing sulphur a somewhat lower sulphur would often machine satisfactorily (except in high speed automatics). Therefore, if physical properties can be satisfactorily met with lower manganese and sulphur, with or without an increase in carbon, it should be entirely possible to obtain the desired machining properties.

A great majority of the commercial bars could probably be placed in Class A, and manganese decreased five to ten points. This would require a very slight modification of the carbon content, to retain the former physical properties. However, this particular item involves the effect of sulphur on surface, and a discussion of this is included at the end of this memorandum.

Sheet Steel and Strip Steel is also divisible into both Class A and Class B. The consumption of ferromanganese in sheet and strip is the lowest per ton of all the products listed in the table, but because their products consume about one-fifth of the ingot output, even a decrease of one point in the average will save about 5% of the manganese required by the product and 1% of the total ferromanganese for the entire steel industry.

It is the opinion of the Committee that an average manganese content can be lowered to 0.35% max. without endangering production schedules or quality of product (except for special cases) and that on present products steel makers should therefore decrease manganese as far as practicable.

Some sheet and strip fall into Class B. No considerable reduction can be considered in these without considering changes in design of finished products to give workability in a steel of lower manganese content. For example, if the general designs in use five years ago were again used for products now made from sheet steel, it is the opinion of the Committee that a reduction of one-quarter the manganese would be practicable.

Wheels, Axles, and Heavy Forgings — It is the opinion of the Committee that, because only about 3% of the manganese is used, and because of the importance of these products for the public safety, no changes in manganese specification be recommended.

Lap Weld and Butt Weld Pipe — In general, manganese requirements can probably be reduced to 0.25% min., and the producers can work as close to that figure as is possible, con-

sistent with surface quality and physical property requirements.

Seamless Tubing — Present analyses can be adjusted to give the desired physical properties and piercing properties, consistent with the individual characteristics of producing mills. Such an adjustment would involve lowering the manganese with suitable increases in carbon and silicon.

Carbon Steel Plates and Structural Shapes involve two distinct problems, first, physical properties, and second, surface requirements.

With respect to physical properties, it has been demonstrated that except for material which is to be welded, the manganese can be decreased and the carbon content increased. 0.25% carbon is accepted generally as the upper limit for weldability, and it is impossible to reduce the manganese without lowering the physical properties. This is particularly true of the heavier sections.

Surface quality will be discussed later.

Tinplate falls into Class B. Little can be done to lower the manganese content because of the danger of producing bad edges when rolling on high speed cold reducing mills. Moreover, annealing practices generally would have to be changed and difficulties might be encountered in the finished product due to fluting. In some cases it might be possible to reduce the manganese a maximum of three points but even that would cause difficulties.

Railroad Rails fall into Class A. A reduction can be made in manganese at the possible sacrifice of some wearing quality and a possible slight increase in seconds, but for war purposes this qualification might be neglected. It is therefore recommended that an emergency specification of 0.50 to 0.80% Mn be written instead of the present 0.70 to 1.00%.

Manganese-Sulphur Relationships

It is generally conceded that sulphur is probably the most important element affecting the surface condition of steel, due account being taken of normal deoxidation practice. In order to control the effect of sulphur a stated amount of ferromanganese is added to arrive at a given manganese range in the product.

It would appear logical to vary the manganese content of the product with the sulphur content if other elements contributing to physical properties could be appropriately varied to maintain the physical (Cont. on page 698)

Storage of Metallographic Specimens

The Problem

We are interested in knowing what is considered the best solid desiccating material and equipment for preserving prepared microscopic specimens for short periods of time. We are also in need of information on materials which will preserve the prepared surface for a long period of time — say, a year or more.

J. C. HARDGRAVE
Associate Professor of
Mechanical Engineering
Texas Technological College

Suggested Solutions

For Steel Research

For the temporary storage of specimens we depend on cabinets or sterilizers of the type usually seen in doctors' offices. These probably are not as completely air-tight as the ordinary chemical desiccators but they permit easier access to the specimens and, for the space they occupy, they hold a much larger number of specimens. To dry the atmosphere within the cabinet, we prefer "Drierite", which is

dehydrated calcium sulphate containing an indicator to let you know when to renew it.

The material we use as a protective coating for polished and etched surfaces is "Aquanite A", manufactured by Atlas Powder Co., Zapon Division, Stamford, Conn. One part is mixed thoroughly with two or three parts of either acetone or amyl alcohol, and the specimen immersed to a depth of $\frac{1}{8}$ to $\frac{1}{4}$ in., taking care to avoid air bubbles on the surface. The excess material is drained for a few seconds and then the lacquer is allowed to dry with the polished and etched surface up resting horizontally. A thin, even coating is obtained which permits examination of the structure at all magnifications.

When we wish to preserve macro-specimens that have been deep etched in strong acids, we make sure that all acid is neutralized by rinsing in a 5% solution of sodium bicarbonate, followed by rinsing in warm water, followed by alcohol. Before applying the "Aquanite A", as above, we dry thoroughly with a blast of warm air.

J. R. VILELLA
U.S. Steel Corp. Research Laboratory

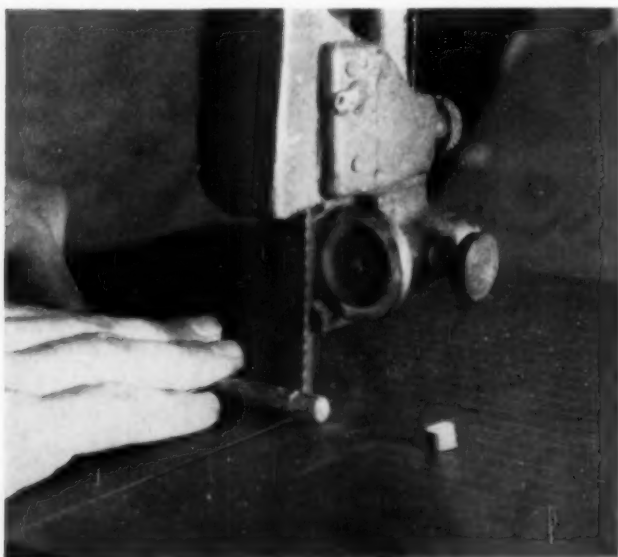
For Aluminum

Storage space does not happen to be a serious problem with our specimens. All we need to do is to keep them in a place where they will not collect dirt from the atmosphere. Of course, under very humid conditions, some type of desiccating material must be employed. For this purpose we have used either activated alumina or calcium chloride. A sterilizer cabinet or an ordinary desiccator has been satisfactory for temporary storage.

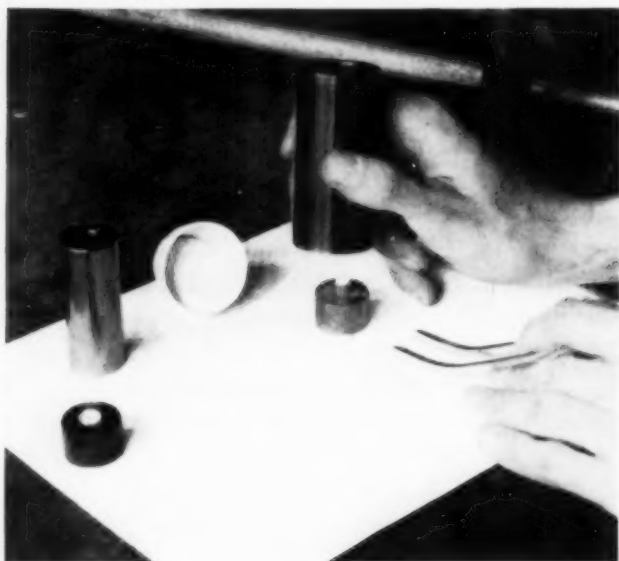
We have seldom attempted to protect polished specimens for re-use at some future time. A very thin film of plastic appears to have some advantages. It is applied by dipping the polished specimen in a solution; the volatile solvent evaporates very rapidly and leaves a thin

Polishing Technique

BEFORE you store metallographic specimens you must prepare them. C. J. SNYDER of Anaconda Wire & Cable Co. took these step-by-step photos of good practice and they have been enlarged into photo-murals in the Development Laboratory at Hastings-on-Hudson, N. Y. Previously published in Bausch & Lomb Optical Co.'s periodical *The Educational Focus*, they were made available through the kindness of R. MILLER of that firm's staff.



Cut out a representative sample in any convenient way. Pieces too small for the fingers may be mounted in plastic



transparent coating, 500 to 1000 Å units thick. This does not interfere with the ordinary examination and protects the finished surface from abrasion and atmospheric action. Some such method of protection would be very desirable and useful.

F. KELLER
Metallurgical Division
Aluminum Co. of America
Research Laboratories

For Magnesium

Anhydrous calcium chloride is a satisfactory material for maintaining a dry atmosphere in the ordinary chemical desiccator for the temporary storage of metallographic specimens.

We have never established the practice of storing polished metallographic specimens for indefinite periods. If re-examination is required after an extended period, we always repolish the specimen. On occasions we have used a coating of vaseline on the surface to retain the polish, and this practice has been very satisfactory. Vaseline may be removed by carbon tetrachloride.

H. W. SCHMIDT
Metallurgist
Dow Chemical Co.

For Copper Alloys

The desiccating material formerly used in chemical balances was concentrated sulphuric acid; another material often employed was calcium chloride. Both of these have certain disadvantages. A new preparation has been offered by G. Frederick Chemical Co. which has the trade name "Desicchlora", and which we believe is anhydrous barium perchlorate. It can be secured through chemical supply houses.

If large sections of bars or castings are machined, polished and etched, such a surface may be preserved temporarily by coating thinly with white petroleum oil such as that formerly designated as white Russian oil. For purposes of photography or further examination, this oil may be removed very readily.

In lacquering, we would employ a clear, white lacquer such as that used by jewelers to protect sterling silver articles. In fact, almost any good grade of clear lacquer will do, after thinning as recommended by the supplier. If the surface is large, the lacquer may be sprayed on, but a small surface may be dipped and the

excess drawn or jarred off, after which the specimen should dry in a perfectly horizontal position. A camel's hair brush may also be used but brush marks are apt to remain unless the operation is very quickly performed.

C. H. DAVIS

Assistant Technical Manager
American Brass Co.

For General Practice

I have always stored prepared specimens in an ordinary glass desiccator containing calcium chloride. This seems to be satisfactory for the few days that a specimen may be of active interest. In some cases we use a vacuum desiccator.

I have not resorted to lacquering to preserve specimens for an indefinite period. We prefer to repolish and re-etch if necessary. The brilliancy of the etch on most steel specimens deteriorates so that from choice we think it is better practice to refinish on the laps rather than to store a specimen for future use with the original preparation. If we were preparing a large number of specimens each day the story might be different. If the specimen is mounted in lucite, mineral oil probably would be better than lacquer.

The stainless types of steel keep very well without lacquering. Some of the non-ferrous metals should be re-prepared, as the surface deteriorates quickly.

FRANCIS F. LUCAS

Bell Telephone Laboratories

For High Alloys

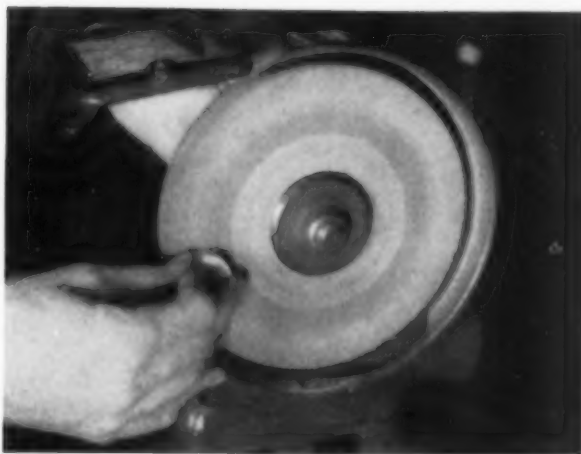
No lacquers have been satisfactory for protecting micro-specimens indefinitely. Our practice in this regard has been to store specimens in indexed envelopes, and when occasion arose for later examination, a fresh surface is prepared. Lacquers of vinylite with a suitable solvent such as acetone are used, however, for preservation of macro-specimens.

W. D. FORGENG

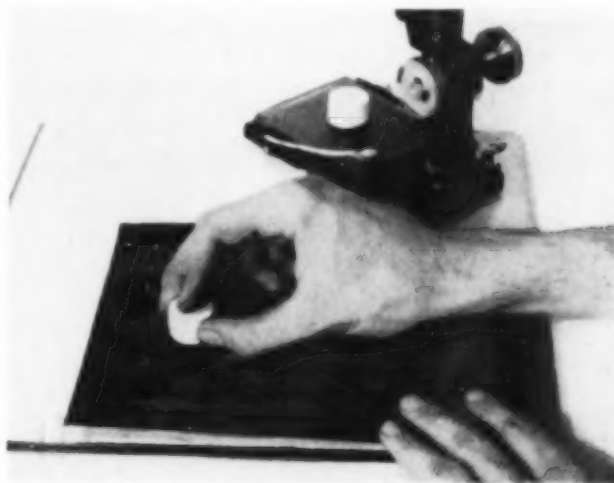
Union Carbide and Carbon
Research Laboratories

For Engineering Alloys Generally

We use calcium chloride in the tray provided with the Buehler specimen cabinet. Metallographic samples have been examined without difficulty at magnifications of 100 diameters



Mounted or unmounted, the specimen must be smoothed flat. An appropriate emery wheel removes large burrs. Note the wire-glass shield to protect the man who is too busy to don goggles



Smooth grinding is done on a series of emery papers, laid on plate glass. Rub in one direction only, crossing scratches with motions on successively finer grit. If the surface looks smooth under a 7-power glass, it is ready for the laps



Rotating plate, covered with broadcloth, is wetted with an emulsion of fine abrasive, lubricated by water drip, and used for lap. Three wheels, with graded abrasive, produce the final mirror polish

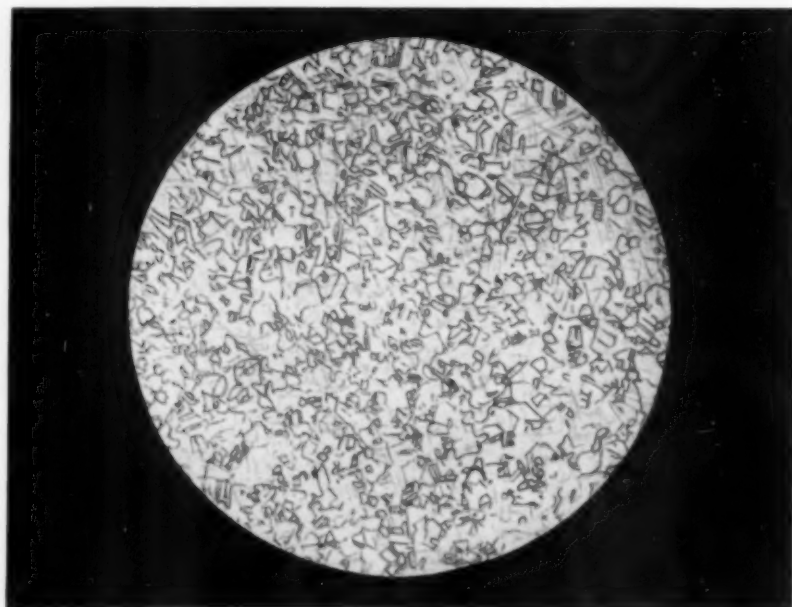


Etching requires skill and reagents to bring out the desired contrasts in sequence. Watch glass, etchants, solvents, wash bottles, hot and cold water, hot air drier — all come in handy



Finally the specimen may be viewed optically and photographed for the record. Modern metallurgical microscopes with inverted stage and binocular eyepieces simplify the examination

In this case it was oxygen-free copper, etched with bichromate solution to develop grain boundaries. Magnification 100 diameters



after a five-month period. No attempts are made to lacquer or otherwise coat samples for examination at high magnification; desiccated samples must be lightly repolished and re-etched.

For macro-samples etched in acid, and where corrosion is aggravated, a very dilute solution of clear lacquer (cellulose nitrate) is poured on in excess, and carefully drained toward a corner of the piece. Photography up to 15 diameters is satisfactory.

D. M. McCUTCHEON
Chemical & Metallurgical Dept.
Ford Motor Co.

For Iron and Soft Steel

For the past few years we have used activated alumina in Fisher "desiccocoolers" for temporary preservation of micro-specimens.

A few attempts at preserving samples for a long time have not been very successful. About two years ago we coated some samples with Canada balsam and others with clear lacquer. Some of these samples are in fair condition today, but we are not able to make a specific recommendation of a coating that will be perfect for any period of time.

R. S. BURNS
Supervising Metallurgist
American Rolling Mill Co.

For Alloy Steels

We have found both calcium chloride and magnesium chloride satisfactory desiccants for temporary storage of metallographic specimens.

Almost any lacquer will serve for long-time protective coatings if the specimens are stored in a dry place. Two of the best lacquers that we have used are Stonite 4100, marketed by Stoner and Mudge, and Murphy's Outside Lacquer.

A. M. TALBOT
Research Laboratory
International Nickel Co.

By Robert C. Stewart

Metallurgist

*Apco Petroleum Products, Ltd.
Leaside, Toronto, Canada*

Metallurgical Mysteries

Dirty Work at the Ball Game

ONE FINE summer's day, on a Saturday to be exact, the chief suspect in the crime about to be described (though unaware of any criminality at the time) innocently planned to go to the baseball park and help cheer the local team to victory in the crucial game of the season.

On the morning of that fateful day, while carrying on with his regular occupation—that of a heat treater—our man was preoccupied with thoughts on his favorite sport, possibly even speculating on the probability that he could wangle a small bet on the big game from Joe, an ardent rooter for the enemy. At any rate, he was quite carried away by his meditations, so that he nearly neglected a large punch which he had been told to get out *for sure* that same day.

Even though the punch was a big one—over 6 in. diameter and 5 in. thick—at about 9 o'clock he first became suddenly very conscious of its presence. Time was short, perhaps even too short, yet to avoid bringing a barrage of hard words crashing down on his shoulders, he decided to heat treat it before going home for lunch.

Being a good man, he carefully preheated the punch. While this was being done, he checked the type of steel and found it was a manganese oil hardening steel, a well-known

brand. With this in mind he planned to quench in oil from 1470° F. which seemed to him to be the best treatment for a piece of this size. Nothing wrong with this general plan of the campaign. He carefully transferred the punch to a controlled atmosphere furnace held at 1300° F., and when punch and furnace had equalized at this temperature, a little more heat was turned on and the whole gradually raised to 1470° F. After soaking for a period, maybe a little short, but deemed to be satisfactory in this emergency when time of lunch and "play

ball" was approaching, our suspect carefully quenched the punch in oil.

While in the midst of this operation his eyes glanced over to a large wall clock, and he nearly dropped the punch when he noticed it was now 11:30. Recovering quickly, full attention was again given to the swishing of the heavy punch to and fro, and he began pulling it from the oil at intervals to see if it still smoked, and finally began touching it with his bare hand. As soon as it felt "cool", he rushed it to the tempering oil, which by this time was conveniently at 375° F., and placed the punch therein. At 12 noon sharp, he turned off the heat under the tempering oil and, leaving the punch there to cool with the oil bath, departed with a clear conscience, to enjoy a fish fry and what was scheduled to be a very exciting ball game. It was.

By the following Monday morning our unsuspecting suspect had recovered from the excitement, but on getting to work found the plant superintendent and the inspector both mysteriously staring at the aforementioned punch—now strangely enough in two pieces! (By what mysterious guidance the boss can beat you to work and just as mysteriously find the broken tools before you arrive is one of the mysteries too deep for even Sherlock Holmes.)

Fracture Surface of 6-In. Punch Which Was in One Piece When Placed in the Tempering Bath at 375° F., but in Two Pieces When Fished Out Cold Next Morning



At this point Charley Chan was called in (Mr. Holmes and Dr. Watson being busy on another case). After a quick glance around the room Mr. Chan began to mutter, "Velly simple, Chally Chan have clue." And such was the case.

As pointed out by Mr. Chan, the broken punch showed two entirely different fracture surfaces, an outer one which was quite fine grained, and an inner one which was coarsely crystalline, enough even to show on a photograph, and darker in color. The outer area tested an average hardness of Rockwell C-62, the value which might be expected after such steel is properly quenched and tempered. The inner zone tested C-64—harder, when it by rights should have been softer.

From these simple observations Charley Chan reconstructed the crime. When our heat treater friend (or should we call him a friend?), torn between his desire to consume the fish fry and also see batter-up in the first inning, to say nothing of the fielding practice, and the desire to serve his employers to the best of his ability, removed the punch from the quenching oil as soon as the outside was cool enough so as not to vaporize the adhering oil and smoke when held in air for a few seconds, or even bear touching with his finger, and transferred it to the tempering oil—it was *then* that he committed his crime!

Even though the outside of the punch was for all practical purposes cold, the center was still at some higher temperature, certainly above 300° F. As Mr. Chan sagely observed, "Heat treater should consider excellent works of Davenport and Bain on isothermal transformation; now old story that transformation, during quenching to martensite, waits until hot steel no longer hotter than three hundred F." He might have added that the extra manganese in this toolsteel prolongs the interval in which the austenitic structure remains dormant before transformation to martensite.

It is evident, therefore, that a transfer to the tempering oil *before the entire tool* has been cooled to below 300° F. and held there for some

little time, would merely retain all material that remained above 300° as dormant austenite, and this austenite remains as such for a very long time if its temperature is above 300° F. Normal tempering would occur in those martensitic regions at the surface that transformed during

the original cooling to below 300°, while the dormant austenite would only transform later when the tempering oil gradually cooled to below 300° F.

This delayed transformation would take place rather abruptly, and with considerable expansion. Inasmuch as this would occur in deep seated material in the middle of the punch, it was able to split the unyielding outer martensitic shell. The above observations are substantiated by the uniformly higher Rockwell hardness in the core. The martensite that first formed in the outer region was let down slightly to C-62 in tempering; the martensite later formed in the core was not tempered, and has higher hardness. Upon re-tempering the broken tool for a similar period at 375° F. the core hardness also dropped to C-62.

To prove the accuracy of his solution, Charley Chan was able to indicate that much heat is stored in the interior of a large piece of steel after the surface has been quickly cooled to room temperature. Mr. Chan had the culprit reheat one of the halves to 1470° F. and quench it as before until our baseball friend said it was "fully quenched". He then offered to buy him a season ticket to all the remaining baseball games, if he could hold the steel in his bare hands for 5 min. It was a safe offer, for the actual surface temperature reached was 285° F., as measured by a contacting mercury thermometer, thus indicating some considerably higher temperature within.

"Remember," Confucius say, "He who fail to cool tool, poor fool."

FOOTNOTE FOR THE RECORD: It is interesting to note that the replacement punch, and many other large sections, were successfully hardened by leaving them in the quenching oil for some time to insure full transformation. This time may amount to 30 min. or more. Of course, the oil temperature should not be too low, but anywhere between 70 and 110° F. is quite satisfactory. ☞

By R. P. Koehring

Metallurgist
Moraine Products Division
General Motors Corp.
Dayton, Ohio

Sintering Furnaces and Atmospheres

*A chapter from a forthcoming book
on Powder Metallurgy, edited by John Wulff*

THE SINTERING PROCESS is the step in powder metallurgy that bonds together the particles of powder which compose the article to be sintered, and imparts to the article many of the properties which make it such an interesting subject for consideration. "Sintering" may be defined as "the process of heating the article to a temperature below the melting point of the highest-melting constituent for such a length of time and in such an atmosphere as will impart to that article the properties which will permit it to serve its useful purpose".

Very little has been written about the sintering methods and equipment used in modern production. This discussion will present some observations on the sintering of porous metal bronze bearings and parts molded from powdered iron, and is based on large-scale manufacture of such parts. It may or may not apply to other metals. However, since porous bearings have accounted for the largest tonnage of metal powders and also the greatest number of parts, it seems proper to base this discussion on that phase.

Early Developments in Sintering Furnaces
—It may be of interest to review some of the steps leading to the modern practice of sintering in continuous furnaces with controlled atmospheres. In the early experimental development

of bearing techniques, about 1921, the first briquettes of copper, tin, and graphite powder were packed in lampblack in a closed container and heated overnight at around 1400° F. This practice produced an article free from oxidation and was a suitable technical method except that it was uncommercial. Other ways of sintering were also tried, such as heating in pure hydrogen, raw natural gas, ammonium chloride vapors, and in carbon dioxide obtained by the decomposition of limestone which was included in the

sintering container. None of these was practical from a production point of view.

The next step, about 1922, was to borrow from known practice and use carbonaceous compounds, such as are regularly used for carburizing steel parts, to produce the required atmosphere. The briquettes were simply packed in carburizing boxes, covered with carburizing compound, and heated overnight in an electric box-type furnace at about 1400° F. After the details were worked out, this proved to be a satisfactory sintering medium and was used for quite a while. Figure 1, page 658, shows a pair of these; the workman is charging a small container into which the parts had been packed.

This process also became commercially impractical, and it was realized about 1928 that some form of continuous process was the only solution to the problem. Inquiry revealed that such a furnace had not yet been developed, so a compromise was made. Round pans of heat resisting alloy sheet were used; they consisted of a bottom pan with a fairly tight-fitting lid of the same shape but which also fitted over the bottom of other pans in such a way as to seal the joint. Briquettes were packed in these pans and conveyed through an open gas-fired furnace, and when the pans emerged from the discharge end of the furnace, they were cooled in air. The

work formed its own atmosphere during the sintering operation, and the pans were sealed sufficiently so that no appreciable oxidation occurred on cooling.

Reports of flue gas generators producing a rich or non-oxidizing gas were then appearing in the literature, and a crude model of one of these was built in 1933. A tool hardening furnace was fitted up with a small cast alloy muffle, and into this muffle and its cooling zone the controlled rich flue gas was conducted. This little furnace had a heating space about 2 ft. long divided into two zones, 8 and 16 in. respectively, with a baffle between. Burners on each of the zones were separately controlled so that different temperatures could be automatically obtained.

The muffle in this furnace was about 4 by 3 in. inside cross section, and arranged so that heat resisting alloy trays about 4 in. square could be pushed through one after another. A prolongation for cooling was also attached to the discharge end of the muffle. The gas generator consisted of a burner for natural gas, firing into a closed combustion chamber; the gas composition was controlled by adjusting the color of the flame so it was green. With this furnace, certain fundamental information was obtained which served as a basis for the design of a larger continuous furnace.

Sintering Effects

Before going on to describe the present equipment for mass production, it may be well to indicate some of the major requirements of the sintering operation—as reflected in dimensional change in the compact—that gradually evolved from the use of the simple furnaces already described. Size changes are of special importance to the bearing industry, where tolerances are the least of any specified for machine parts. Sintering may cause growth or shrinkage, and depends on a

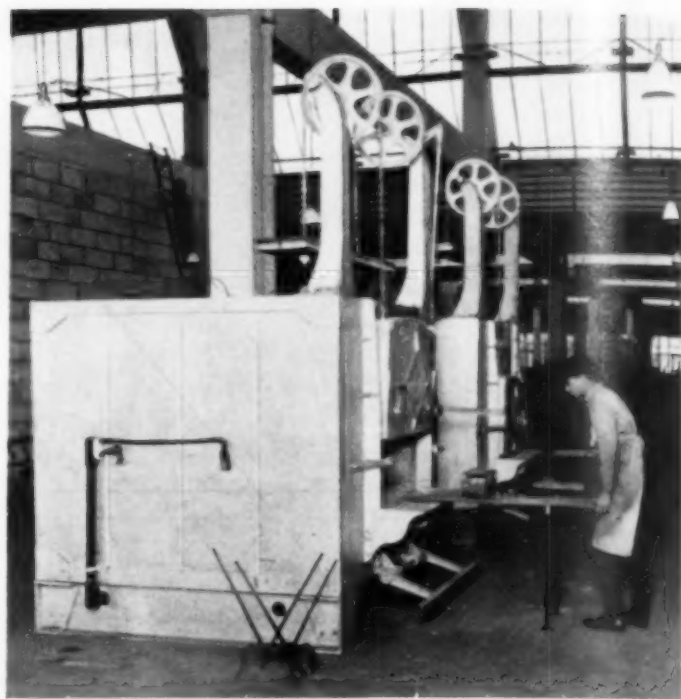


Fig. 1 — Furnaces Similar to Batch Type Carburizers Used in 1922 for the Sintering of Porous Bearings

number of possible variables such as (a) the character of powder used, (b) the composition of the mixture, (c) the density to which the part has been briquetted, and (d) the manner of sintering.

Since the effect of these variables is manifested only after sintering has been done, a consideration of each may be of interest. In actual practice, there is usually a final sizing operation to correct small dimensional variations; however, it is the aim to reduce these variations as much as possible and in some cases, as in making gears, to eliminate sizing entirely.

Character of the Powder—A lot might be said about this; for the present, only the particle size distribution will be considered. It will be understood that variations in particle shape, source or method of manufacture, apparent density, flow rate, or purity may also affect the uniformity of the final product. As a general rule, the coarser powders, or those having a larger percentage of coarse particles, will

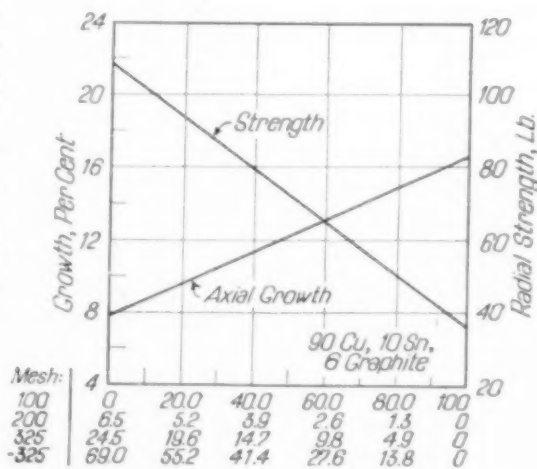


Fig. 2 — Strength of Small Bushings Decreases and Axial Growth During Standard Sintering Increases With Coarse Copper Powder

form a bearing that will grow more or shrink less than with fine powders.

In Fig. 2 the lines show the effect on dimensional change and strength of some bushings resulting from variations in the percentage of a coarse copper powder. The base composition is 90 parts copper powder, 10 parts tin powder, and 6 parts graphite. The base copper powder is a standard 150-mesh grade, having a particle size distribution as follows: 6.5% on 200 mesh, 24.5% on 325 mesh, and 69.0% through 325 mesh. Additions of a 100-mesh copper powder were

The diagram on the right of Fig. 3 shows the effect of varying the graphite content from 1 to 4%, maintaining a 90-10 Cu-Sn ratio and using the same sintering temperature. Increasing graphite increases the dimensional changes and decreases the strength. At 1% graphite the radius shrinks slightly.

Briquetting Pressure — Another important variable is obviously the briquetting pressure (or the density to which the powder mixture is compressed). Figure 4 (below) shows a group of curves indicating these changes, due to briquetting pressures from 30,000 to 60,000 psi., on a mixture of 90 parts copper, 10 parts tin, and 2 parts graphite. Strength, density, and dimensional change increase with increasing briquetting pressure, while green length and percentage of voids or porosity decrease.

Manner of Sintering — One of the factors which was early recognized is that the dimensional change during sintering varies with the rate at which it is heated. There has been much discussion as to the reasons for this, and it is doubtful whether all the causes are yet known; it is probably a resultant of several

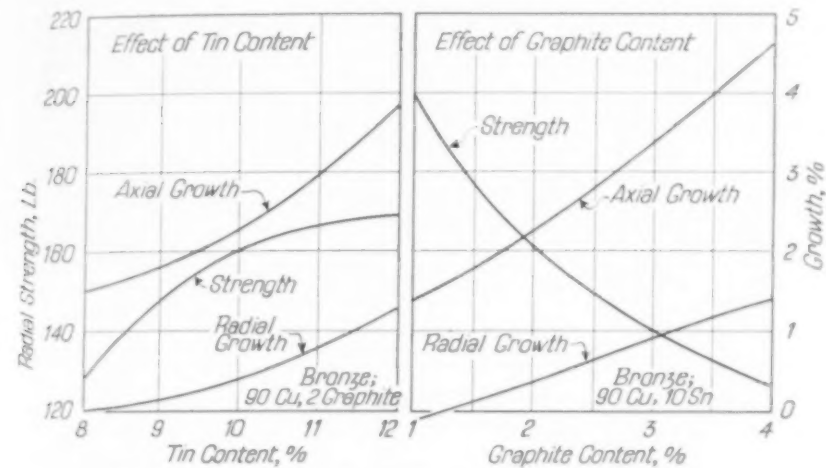


Fig. 3 — Diagrams Indicating Variations in Strength and Dimensional Change of Sintered Bronze Bushings as the Content of Major Constituents Changes

made in order to vary the particle size distribution, and the specimens were sintered according to a standard practice. Specimens consisted of small cylindrical bushings and the dimensional changes as well as the radial loads required to crush the specimen were determined. It will be noted that with increasing coarseness the strength decreases and the longitudinal growth increases.

Composition of the mixture from which parts are briquetted affects their physical properties as well as the dimensional change during sintering. To show this, data about a common porous bronze bearing may be quoted. Its formula is 90 parts copper powder, 10 parts tin powder, and 2 parts graphite powder. Figure 3 shows, at left, the dimensional change and strengths from varying the tin content from 8 to 12% and sintering at a constant temperature (1500° F.). It will be noted that with increasing tin content there is an increase in dimension, both radially and axially, and an increase in strength.

influences, either positive or negative in their effect. In a tin-copper mixture, melting of the tin particles can readily result in a shrinkage — if no other influence is in operation to cancel

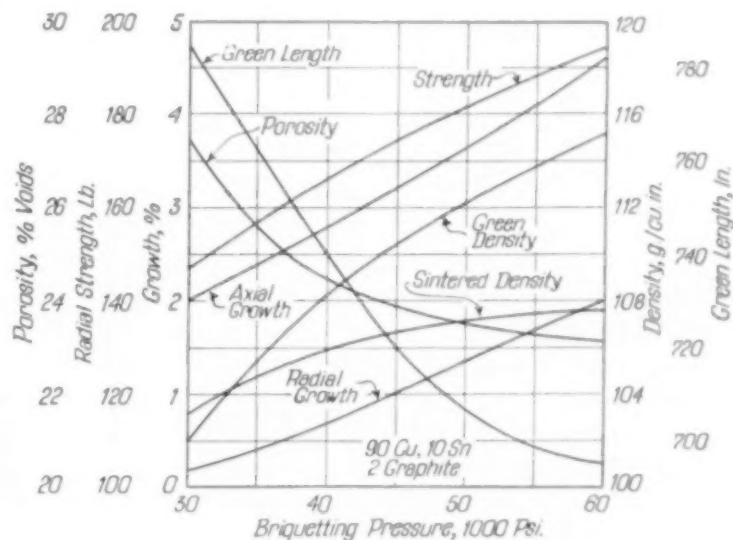


Fig. 4 — Strength, Density and Dimensional Change Increase With Increasing Briquetting Pressure, While "Green" Length and Porosity Decrease

this effect. If the rate of heating is greater than the rate of diffusion of tin into copper, we might expect a larger proportion of liquid constituent to be present at a given instant, with a consequent effect on the final dimensions. Usually, if a briquette of copper, tin, and graphite is rapidly heated, it will either grow more or shrink less than if it is slowly heated. These two statements appear to be contradictory, but as stated before, the result we observe is a net result and sintering is a complex phenomenon.

Gas Evolution—When metal powder briquettes are heated, large volumes of absorbed or entrapped gas are liberated; the faster the rate of heating the greater is the gas pressure in the porous interior, and this pressure is sufficient to change the volume of the briquette during sintering.

These gases may come from several sources. The air contained in the porous structure of the briquette will expand on heating and must

either CO_2 , CO, or water vapor will be formed which will add further to the gas volume which must escape through small orifices in a short time. Often there is added to the powder mixture either a lubricating agent—usually an organic compound which evolves gases when heated—or an organic void-forming material which also evolves gas.

When all these sources of gas evolution are considered, it can readily be seen that considerable pressure can be developed within the porous structure during sintering. The rate at which these gases escape depends on the density. In briquettes of low density as compressed the pores are fairly open and the gas can escape more readily and so its effect is minimized. If the rate of heating can be controlled, the rate of gas evolution and thereby the growth of briquettes during sintering can be controlled.

From numerous experiments on the effect of the rate of heating, some cylindrical bushings were sintered in a furnace having two zones of temperature control, the first zone, or charging zone, being so arranged that its temperature could be different from the last, or soaking zone. The rate of heating was varied by adjusting this temperature, thus providing a variable thermal head. If this "thermal head" in the charging zone was 1450°F ., the radial growth was 0.25% and the axial growth 1.40%; both increased in a linear manner up to a thermal head of 1550°F ., when radial growth was 1.40% and axial growth was 2.5%.

Time of heating was also studied. For a 90-part copper, 10 tin, 2 graphite mixture no significant changes were observed in strength, porosity and axial or radial growth when varying the time at heat from 5 to 30 min. Figure 5 shows that important changes occur at about 1475°F . This is interpreted as the point at which a liquid constituent just begins to form under equilibrium conditions.

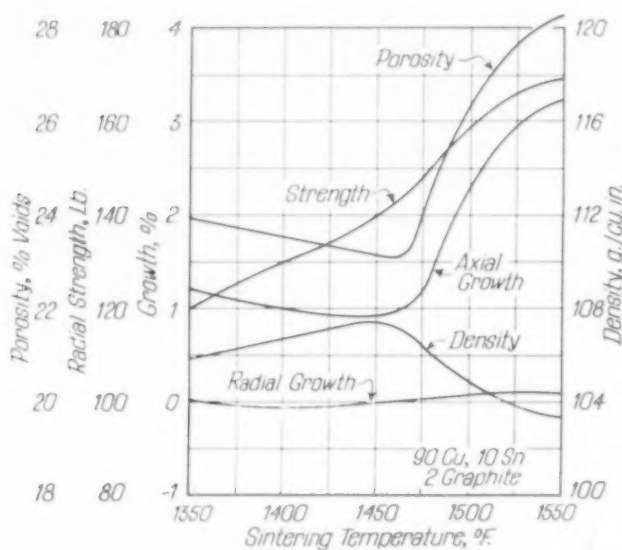


Fig. 5—Physical Properties of 90-10 Cu-Sn Briquette Containing 2% Graphite Experience Large Changes When Sintering Is Done Beyond 1475°F .

escape. (Some of the air may even be compressed if it is caught in a cavity which is sealed off from the outside; heating will cause such a gas bubble to expand, break through its seal and escape.)

Another source is gas films adsorbed on the very large surface which a metal powder presents. Most of this gas will be evolved when the powder is heated. Furthermore, if any reducible oxide films are present on the particles when heated in a reducing atmosphere or in contact with a reducing agent (carbon or hydrogen)

Production of Various Sized Parts

In the manufacture of porous metal bearings by powder metallurgy a large variety of sizes and shapes must be handled. There are thin walled bearings and heavy walled bearings, and they must be heated during sintering at as nearly uniform a rate as possible.

In the sintering of parts molded from iron powder the most important considerations are time and temperature of sintering. The longer the time and the higher the temperature, the

greater shrinkage. In a Cu-Sn-graphite mix the shrinkage is usually low and varies with the amount of graphite; in fact, the dimensional change may be a growth if sufficient graphite is added. (The shrinkage of molded iron powder is also dependent on a large number of variables which may originate before the sintering step, in general, similar to those just discussed.) After all the physical variables of powders,



Fig. 6 — Operator Is Placing a Tray of Green Bearings on Traveling Mesh Belt at Charge End of Continuous Furnace Diagrammed Below

mixtures, and briquetting pressures are controlled it is evident that the furnace must have very close temperature control and uniformity of temperature distribution.

A suitable furnace for carrying out the sintering operation will now be described.

A photograph of the charge end is shown in Fig. 6, and Fig. 7 shows diagrammatically a

longitudinal cross section. This furnace has a heating and a cooling zone into which is conducted the controlled atmosphere. Material to be sintered can be conveyed either on a mesh belt or by a roller hearth. The atmosphere gas is admitted into the cooling zone from whence it flows in both directions, enough escaping from the discharge door to maintain a gas seal but most of it going through the furnace counterflow to the work and maintaining a seal at the charge end. Since the previously cooled gas is admitted into the cooling zone, it serves as an additional cooling medium. The furnace itself is divided into three zones of temperature control, and the first zone on the charging end is further separated from the rest of the furnace by a baffle.

Most of the heating is put into the first zone in order that the work may be brought up to temperature quickly and at a controlled rate. The dividing wall is to maintain a temperature differential between zones, when such is desired. Work is carried through on trays at adjustable speed. If a heavy part is being sintered, the temperature of the first zone is increased so that the rate of heating will be the same as in lighter parts.

When this furnace is used for sintering parts molded from iron powder, it is operated at about its maximum temperature in all three zones. Therefore, no additional thermal head can be utilized. However, advantage is taken of the large heating capacity of the first zone in bringing the work up to the soaking temperature as quickly as possible, thereby reducing the

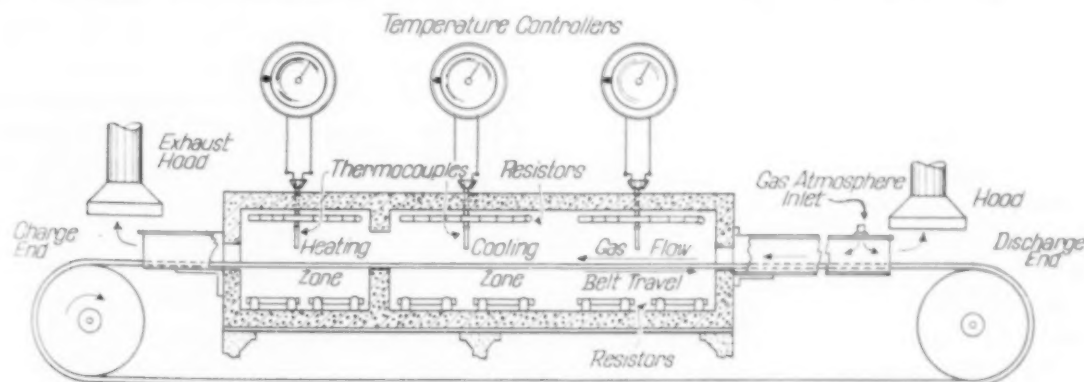


Fig. 7 — Schematic View of Modern Continuous Sintering Furnace

over-all time of sintering without the necessity of building a very long furnace.

Other design features include provisions for maintaining a uniform temperature and heating rate from one side of the furnace to the other. The outer rows of work on each side are subjected to a greater amount of radiation than the center rows unless elements are suitably disposed and baffled trays designed.

Interested readers may turn back to METAL PROGRESS for August 1940, page 173, for a description of a more highly specialized furnace, wherein copper-nickel powder is sintered and bonded to steel strip continuously, then compacted and babbitted.

Sintering Atmospheres

Choice of a suitable atmosphere is of greatest importance. Because of the large surface area of the powders used and the porosity of briquettes, any specific effect that a gas may have on the surface of a solid chunk of metal would be greatly increased.

The first requirement of a sintering atmosphere is to avoid or protect from gases which form undesirable surface films, such as oxides. The second is to reduce such films if they are present on the powders before mixing and briquetting. Nitrogen will perform the function of protection but will not reduce any oxides. Hydrogen will do both but is too costly for most commercial operations. In some operations on copper and its usual alloys, pure CO_2 might be used as well as steam.

Vacuum sintering has been given some study, and it offers an interesting possibility for researches wherein gas is entirely eliminated. It would be costly and difficult for production operations. Modern combustion generators have been described from time to time in METAL PROGRESS and offer a wide variety and combination of gases suitable for most of the present needs.

As stated before, correct atmospheres were first obtained by including materials within the container, which when heated generated a suitable gas. This

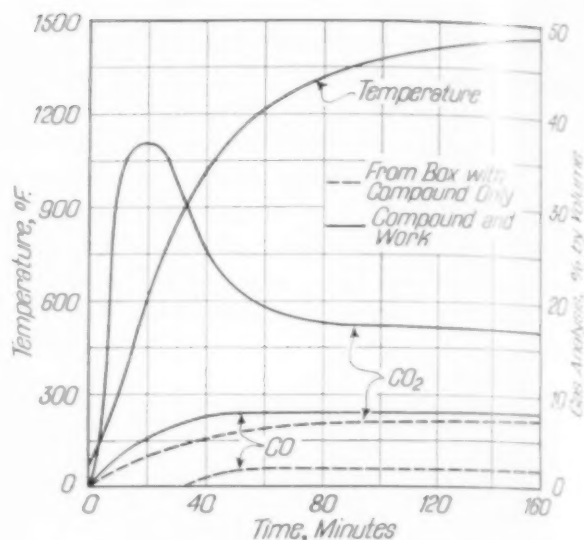


Fig. 8—Two Containers of Spent Carburizing Compound Were Heated for 3 Hr. at Rising Temperature. One contained green bushings, and evolved much higher percentages of CO_2 and CO

became a rather complicated and unsatisfactory procedure, because it was found that new material had to be added very slowly or the atmosphere would change rapidly, and this change affected the properties of the sintered work.

Gases From Compacts

As an instance, Fig. 8 shows what happens to an atmosphere generated merely by heating a carburizing compound for three hours without any work in it. The same figure also shows the gas analysis from a second sintering container containing another batch of the same compound and heated simultaneously, but having packed into it some copper, tin, and graphite bushings containing salicylic acid to increase their porosity. The gas samples from the two containers were of considerably different composition, probably because of the thermal decomposition of the volatile organic compound.

With the development of the modern gas cracking units the problem has become much more simple and satisfactory. They consist essentially of a firebox, burner, and accurate control equipment so that determined amounts of fuel gas and air

(Continued on page 722)

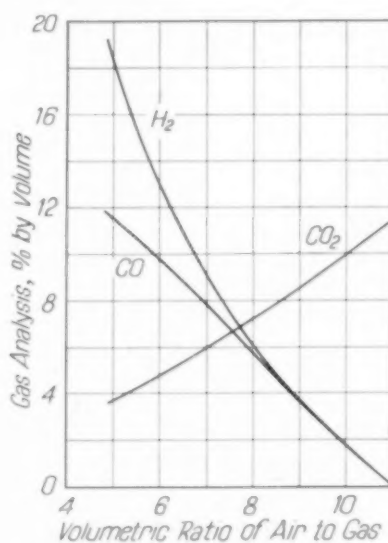


Fig. 9—Approximate Analysis of Atmosphere Obtained From a Combustion Type of Generator Fed Natural Gas and Air

Measurement of Drawing Properties of Aluminum Sheet

INCREASING use of the double-acting press to supplant drop hammer operations in the aircraft industry has warranted investigating the behavior of the various aluminum alloys during the forming operation. If its production possibilities are to be fully realized, the best material and the best die design should be used.

The double-acting press has two distinct functions; namely, stretching and drawing. Forming by stretching gives the material a permanent set by gripping it tightly at the edges while it is being deformed by the action of a punch. Simple stretching is applicable to parts having shallow contours, or at most a deep contour in one direction only, such as skins and cowling. Such a process is fully described by T. H. HAZLETT and M. M. ROCKWELL in Lockheed Aircraft Corp. Research Memorandum No. 1123 entitled "Forming Contoured Sheet Metal Airplane Parts by Stretching." There it is shown that the best material for stretch forming may be selected by finding the material which is capable of the greatest elongation under simple tensile stress, bearing in mind that such elongation may be dependent upon such factors as length of the region being stretched, and condi-

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Research Engineer
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Production Research Engineer
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Burbank, Cal.

tions along the edges of the material.

The process of forming by drawing, on the other hand, involves actual flow under a restraining draw ring and introduces complex stress relationships which make the selection of a suitable material more difficult. The "Mechanics of Deep Drawing" have been explained by G. A. BREWER in a paper of that title published in *Aero Digest* for February 1942. It is there pointed out that during the

process of drawing a simple shape such as a cylindrical cup, each segment of the blank forms a wedge which flows toward the center of the draw die, as indicated in Fig. 1. The material in this elementary wedge undergoes continuous lateral compression; coupled with the radial tensile force pulling it into the cup, this sets up a condition of combined stress which makes it capable of plastic deformations greatly in excess of those obtainable under the simple stretching action of tensile stresses alone. The function of the draw ring is to restrain the tendency of the material to buckle under the lateral compressive stresses.

It can be seen from the above that the determination of the limits to which a given material can be drawn (other than by trial-

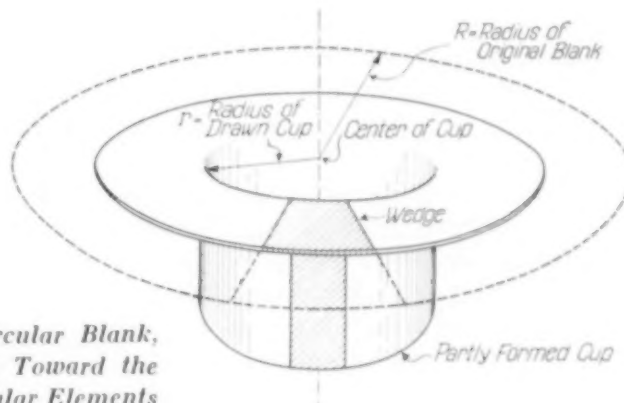


Fig. 1—In Drawing a Cup From a Circular Blank, Wedge Shaped Portions of the Rim Flow Toward the Center and Are Upset Into Thicker Rectangular Elements

and-error) is by no means so simple as determining its limits in simple stretching. J. D. JEVONS in his book "The Metallurgy of Deep Drawing and Pressing" and E. V. CRANE in "Plastic Working of Metals" describe various attempted methods of testing for deep drawing formability. Tearing tests, cupping tests, dome tests, micro-structural examination, and interpretation of standard physical tests have all been used without distinct success.

It is significant that none of the test methods so far described reproduce the actual conditions which occur in a segment of a blank while it is being drawn into the shape of a cup. Since such a segment is wedge-shaped, as shown in Fig. 1, the logical procedure is to make a suitable jig or die through which a wedge-shaped coupon can be drawn. This will simulate the conditions of combined tension and compression which exist during the true drawing operation.

The method described above has been carried to an advanced stage of development at Lockheed Aircraft Corp. The idea did not, of course, originate here, since it has frequently been discussed in the literature. Our contribution has been the technique whereby experimental results of consistent nature and practical value can be obtained. Apparatus has been built which has largely overcome the drawbacks and sources of inaccuracy reported by JEVONS, page 491 of his book above mentioned. Results have been very closely correlated with the results of actual manufacture of complete drawn cups.

Referring to the topmost part of Fig. 2, the die in use at Lockheed has two sloping hardened steel arms between which the coupon is fitted as shown. A cover plate (shown above the jig) is fitted on top of the coupon to prevent wrinkling, and is held in place by a spring-plate (shown at left) whose pressure may be adjusted by set-

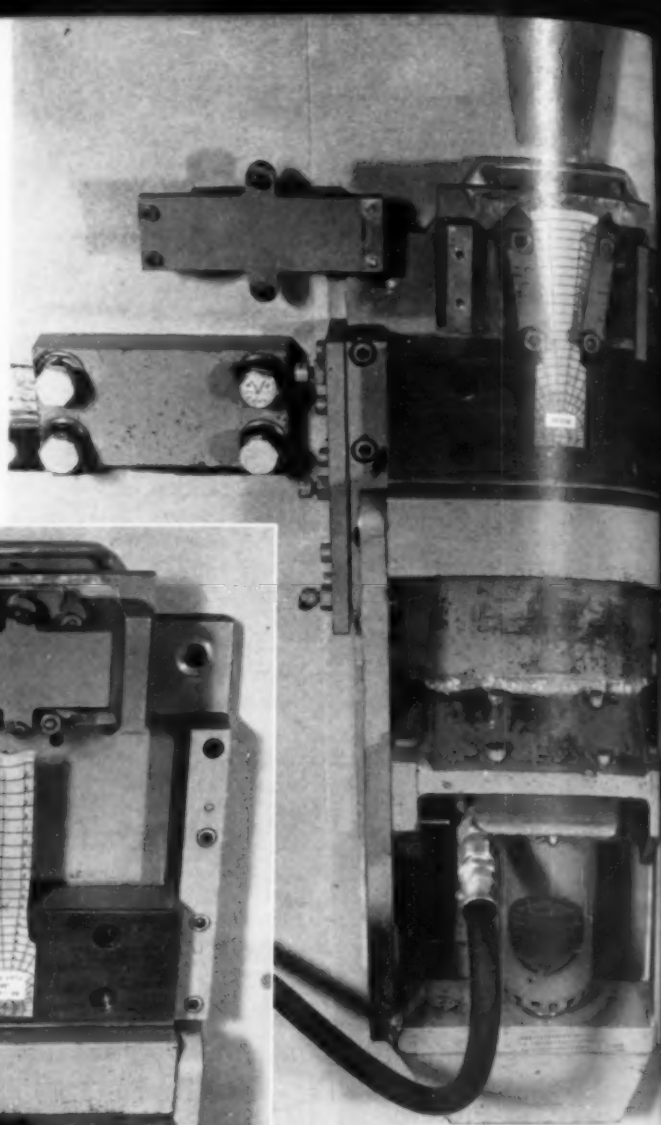
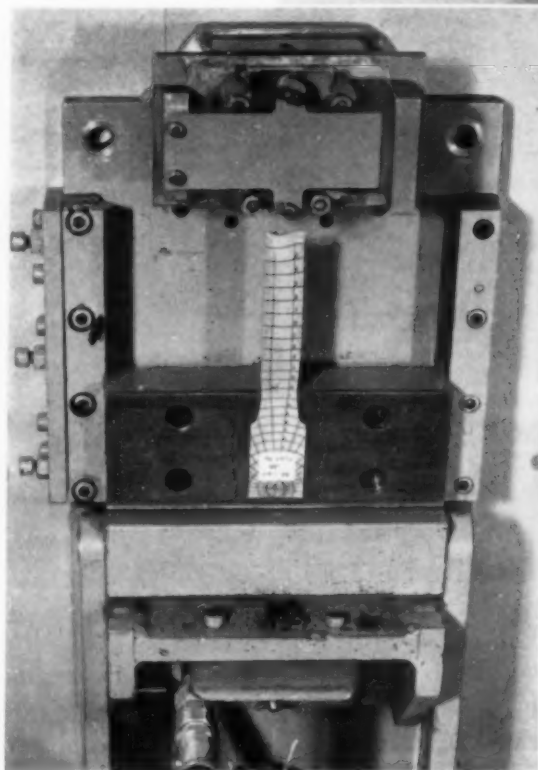


Fig. 2—Sheet Sample (Wedge) With Photo Grid Imprint Is Placed Within Die and Held Down by Filler (Above) and Spring Plate (Small Bar at Left With Ears at Sides). After drawing, by extending the hydraulic jack, the shape of specimen and transformation of grid is as shown at right.

screws. The complete assembly is shown. Instead of the spring plate, pressure may be applied (and measured) in a compression testing machine. The bar with four set screws clamps the lower end in place.

The protruding end of the coupon is gripped and pulled horizontally out of the die, deforming it into the shape shown at the right of Fig. 2. The transformation in the imprinted grid clearly indicates the nature of the deformation which has occurred; lines previously radial have become parallel, giving evidence of lateral compression. The action is directly comparable to that illustrated in the drawing of a complete cup, Fig. 3, wherein the radial lines of the blank are transformed into vertical parallel lines on the side wall of the cup. The straight portion of the coupon after drawing would form part

of the side wall of the cup shown in Fig. 3, and the lower undeformed area of the coupon would form part of the bottom of the cup. The close analogy of action as shown by the grid lines is strong evidence that basically the wedge-draw test represents the actual drawing process to a high degree of accuracy.

Bend at Draw Radius—Of course, there are two obvious points of divergence between the wedge-draw test and the actual drawing operation. First, the test does not reproduce the bend which occurs at the draw radius in an actual drawing operation. A study of the stress factors showed that the controlling factor is the *lateral reduction* which occurs at the draw radius, not the simple bend which also occurs there. Hence it was not considered worth while to reproduce this bend in the wedge-draw apparatus, though this could have been done without too great difficulty. Experimental results indicate such a good correlation between wedge-draw and actual drawn cup tests, that the bend is evidently of minor importance.

Frictional Effects—The second point of divergence between the wedge test and the actual drawing operation lies in the frictional effect between the sides of the coupon and the sloping guides of the die. This effect is appreciable, the lateral compressive load being of the order of 80,000 psi. for 24S-O alclad. The friction load is transmitted to the neck of the specimen and adds to the tensile load at that point, tending to induce premature failure if it is of appreciable magnitude. This effect has evidently been the source of much difficulty in the European experiments, especially due to its seemingly erratic nature; however, it was learned that very slow pulling rates were used and lubricating difficulties were evident.

In building the Lockheed equipment the frictional difficulties were largely overcome by a fast, steady pull in conjunction with a good high-pressure lubricant (sulphurized lard oil with suspended mica) and a well-fitting die to restrict the escape of the lubricant. The fast, smooth pull was obtained by an 8-ton hydraulic jack actuated by a high-pressure oil pump, and closely simulated the action occurring in the

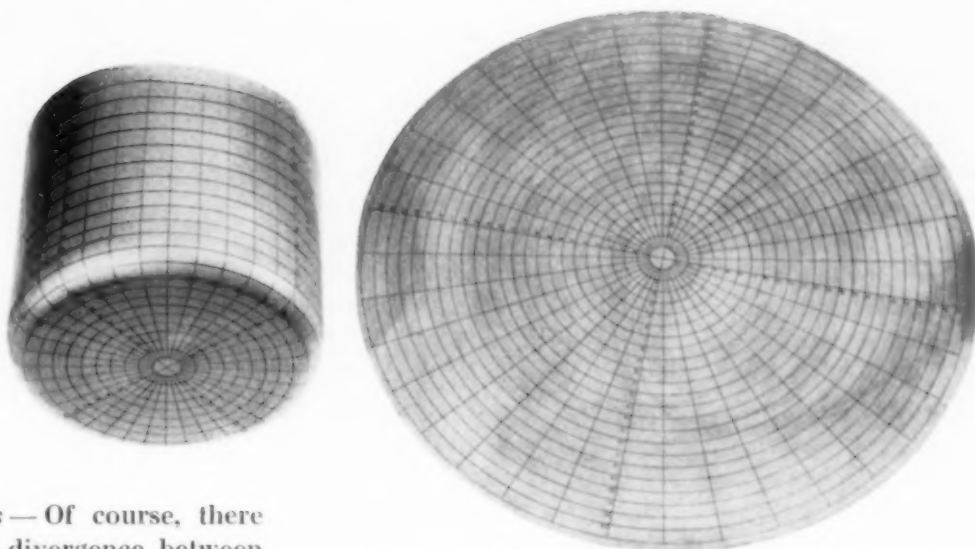


Fig. 3—Circular Blank With Polar Grid, and Cup Drawn Therefrom. Note how radial lines on blank become parallel lines on side of cup

draw press. This not only eliminated erratic frictional difficulties but also took care of any possibility that results might be a function of speed of testing. Figure 2 shows how the pulling jaws (at middle left) travel on accurately machined V-guides to give a perfectly straight, smooth pull.

That edge frictional effects were negligible under the procedure described above is evidenced by the fact that the imprinted grids showed only the most minor distortion near the edges, and that excess thickening at the edges was not more than 0.001 or 0.002 in. Furthermore, test results were found to be very consistent, the length of blank just producing failure during the draw for any given set of conditions being reproducible time after time within a tolerance of $\frac{1}{4}$ or $\frac{1}{8}$ in.

Interpretation of Test

Figure 4 shows the geometry of the coupon and the nomenclature. A comparison with Fig. 1 shows clearly how r , the radius from the original center of applied force to the throat of the wedge-draw die, corresponds to the radius of the cup in the actual drawing operation. R , the outside radius of the coupon before pulling, corresponds to the original radius of the circular blank from which the cup is drawn.

In drawing cylindrical cups the limiting depth of draw is commonly expressed as the ratio $r:R$; the smaller the limiting value the better adapted is the material for deep drawing. In the wedge-draw tests, therefore, results are

expressed in terms of the smallest ratio of $r:R$ (as indicated in Fig. 4) for which the coupon can successfully be pulled through the wedge. In our tests r was held constant at about 3 in. and the values of R were varied to find the limiting condition. Variation in the size of r is not believed to be important in the ordinary sizes of drawn parts. (This has since been verified by numerous tests on drawn cups.)

Table I gives the limiting $r:R$ ratios determined from the wedge-draw test and from drawing of cups from various aluminum alloys, tempers (heat treatment), and thicknesses. The chemical composition of the various alloys may be found in many publications of Aluminum Co. of America. The table is based on tests on about 275 wedges and 100 cups. The minimum hold-down pressures required to prevent buckling under the compressive forces are also shown. These are less for the heavier gages (note the case of 24S-O alclad) because of the greater rigidity of the material. As a result the heavier gages can be drawn deeper because the drawing force does not have to be so great to overcome the friction under the hold-down pressure.

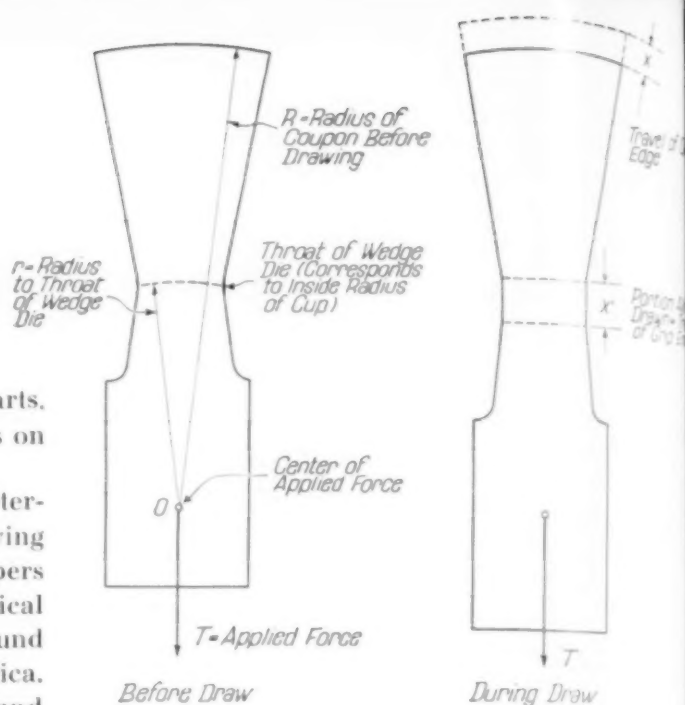


Fig. 4—Geometry of Wedge-Draw Coupons

Table II shows the various alloys and tempers arranged in order of descending formability for pure drawing. The approximate range of the limiting $r:R$ ratio in each group is also shown.

Modes of Failure—The way in which failure occurs when the limiting $r:R$ ratio

Table I—Limiting $r:R$ Ratios and Critical Hold-Down Pressures for Aluminum Alloy Sheet*

Alloy (a)	Rolling Grain	Thickness	$r:R$ Below Which Failure Occurs		$r:R$ Above Which Failure Does Not Occur		Minimum Hold-Down Pressure (b)	Type of Failure	
			Wedge	Cup	Wedge	Cup		In Wedge	On Cup
24S-O alclad	With	0.051	0.49	0.47	0.51		263	Tension	Tension
	Across	0.051	0.49		0.51	0.50	307	Tension	
24S-O alclad	With	0.032	0.51	0.47	0.53	0.51	524	Both (c)	Tension
24S-O alclad	With	0.025	0.55	0.48	0.57	0.52	595	Tension	Tension
	Across	0.025	0.56		0.58		449	Tension	
24S-T alclad	With	0.032	0.65	0.70	0.70	0.73	425	Shear	Shear
	Across	0.032	0.67		0.71		473	Shear	
24S-W alclad	With	0.032	0.55		0.58			Shear	
52S-O	With	0.041	0.50	0.48	0.53	0.50	591	Shear	Tension
	Across	0.041	0.54		0.57		754	Shear	
52S- $\frac{1}{2}$ H	With	0.041	0.58	0.52	0.61	0.54	558	Shear	
	Across	0.041	0.58		0.61		967	Shear	Shear
53S-W	With	0.032	0.57		0.61		785	Shear	
53S-W	With	0.040	0.55		0.58		770	Both	Tension
	Across	0.040	0.58	0.49	0.61	0.52	900	Shear	
53S-W	45°	0.040	0.51		0.53		670	Tension	
61S-W	With	0.032	0.56		0.59		827	Shear	
61S-W	With	0.040	0.55		0.58		770	Both	
	Across	0.040	0.58	0.53	0.61	0.55	900	Shear	Shear
61S-W	45°	0.040	0.53		0.55			Shear	
2S-O	With	0.039	0.52		0.55		530	Shear	
3S-O	With	0.039	0.52		0.54		559	Shear	
3S- $\frac{1}{2}$ H	With	0.039	0.56		0.59		449	Shear	

*For one operation; redrawing will widen the difference in formability between the various alloys.

(a) Code: -O Annealed
-T Fully heat treated
-RT Heat treated and rolled

-W Quenched but not fully aged
-H Cold worked to a hard temper
- $\frac{1}{2}$ H Cold worked to a half-hard temper

(b) Psi., calculated on area of wedge at beginning.

(c) Both tension and shear failures.

Table II—Order of Formability for Pure Drawing

ORDER OF FORMABILITY	ALUMINUM ALLOY	TYPE OF FAILURE	APPROX. RANGE OF LIMITING $r:R$	THICKNESS (INCHES)
Group 1	24S-O alclad	Tension	0.51 to 0.53	0.032
2	52S-O	Shear	0.50 to 0.53	0.041
	2S-O	Shear	0.52 to 0.55	0.039
	3S-O	Shear	0.52 to 0.54	0.039
3	24S-W alclad	Shear	0.55 to 0.58	0.032
	3S-1/2H	Shear	0.56 to 0.59	0.039
	53S-W	Shear	0.57 to 0.61	0.032
	61S-W	Shear	0.56 to 0.59	0.032
4	52S-1/2H	Shear	0.58 to 0.61	0.041
5	24S-T	Shear	0.65 to 0.70	0.032

is reached is also noted in Tables I and II, and indicated by Fig. 5. 24S-O (except for one sheet of fine-grained material) fails in tension in the reduced (straight) portion of the coupon (like specimens 128 and 131, Fig. 5). This indicates that the force necessary to pull the rest of the coupon through the wedge reduction process was too great for the cohesive strength of the material and it failed in simple tension in the region of minimum cross-sectional area. This type of failure corresponds to the tearing sometimes observed in the wall of a drawn cup. It often occurs relatively early in the drawing process.

On the other hand, all the other materials tested failed in diagonal shear in the portion which had not yet passed through the throat of the wedge, as indicated by specimens 71, 72, 83, and 101. This shear failure is a result of the combined action of the tensile and compressive forces and appears to be the end-effect of slippage along diagonal planes of maximum shear

stress. The development of such slippage planes (commonly called "Lüder lines") can be observed just prior to failure in some materials.

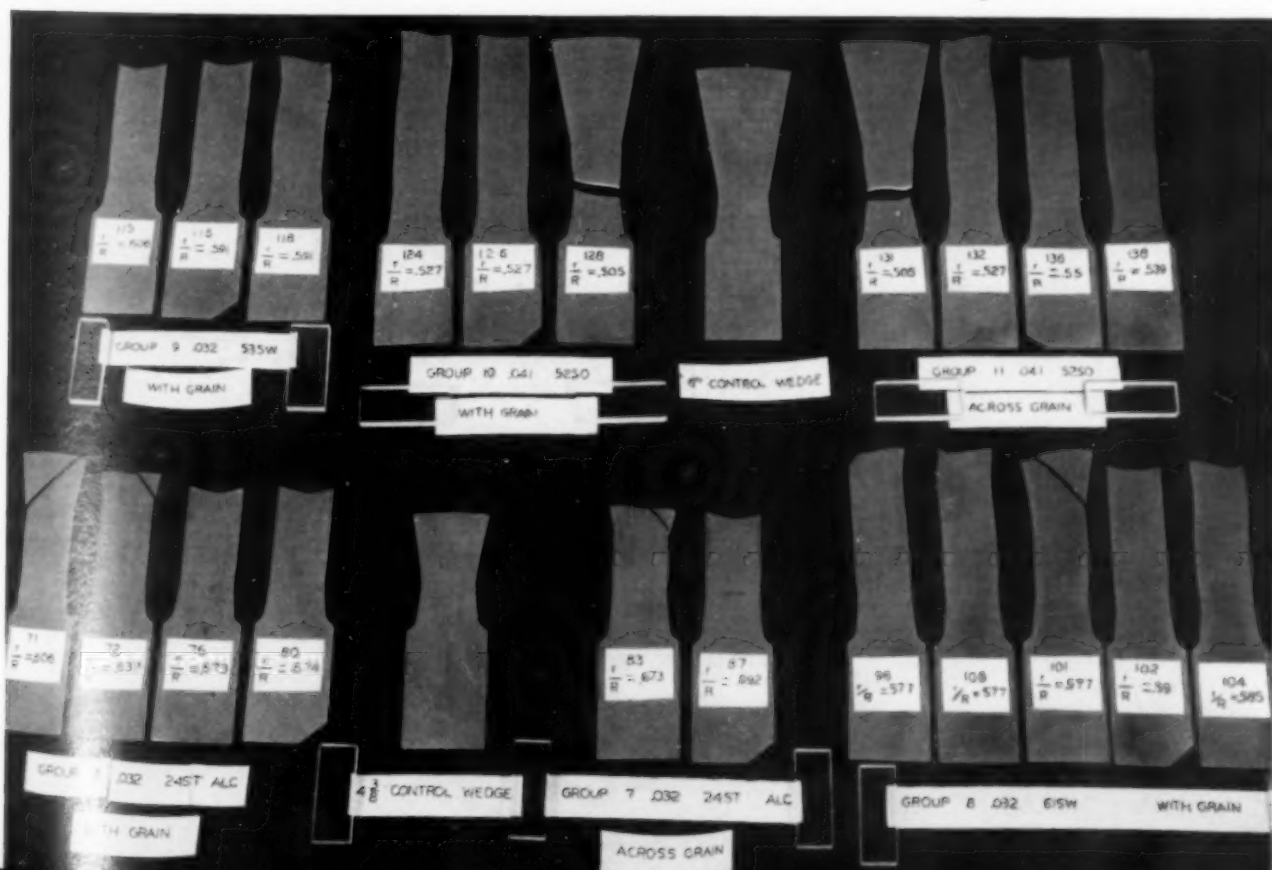
Shear failure in a wedge does not necessarily indicate that the material will fail in shear during actual drawing operations. If shear failure occurs at about the same reduction in wedges drawn *with* the grain as in those drawn *across* the grain, as in 24S-T, indications are that the material will fail in shear during actual drawing operations. If wedges drawn with the grain, for example, fail in shear at higher than average $r:R$ ratios, while wedges drawn in the other direction (across the grain) fail in tension at normal reductions, the sheet is exhibiting strong directional properties which will be evidenced in the drawn part by large "ears" rather than by shear failure when the first limiting $r:R$ value is reached.

Correlation With Practical Operations

Preliminary checks show an encouraging degree of correlation between the wedge-draw tests and the actual limiting ratios found in drawing cylindrical cups.

Figure 6 shows two 24S-O alclad cups, both having an $r:R$ ratio of 0.500. One failed; the other formed successfully, thus indicating that the material was on the borderline of formability. In the same picture are two wedges from the respective sheets, both test pieces having an $r:R$ ratio of 0.505, one of which failed, the other did not. To heighten the accuracy of the correlation, the coupon failed in tension in the neck (typical of 24S-O as already pointed out) and

Fig. 5—Wedges at Limiting $r:R$ Ratios in Four Aluminum Alloy Sheets



the cup failed in tension in the cylindrical wall.

Similar views could be shown of other correlation tests. Of two 24S-T alclad cups, one failed at $r:R = 0.695$; the other formed successfully at $r:R = 0.730$. The corresponding wedge coupons failed at 0.692 and formed successfully at 0.712, showing fairly good agreement. Failure occurred by a shear crack in the upper corner of the coupon and at the upper lip of the cup.

Value of Redrawing—It is common practice with many metals to form very deep drawn parts (i.e., parts with $r:R$ ratio less than 0.5) by using two or more successive draws. This procedure would seem to be valid for material which fails in tension during the drawing process, since the maximum tension load can be reduced in proportion to the number of stages used in the drawing process. But, by theoretical considerations at least, it does not appear that much would be gained by redrawing materials which fail in shear under the combined stresses in the wedge or flange. For the aluminum alloy materials that definitely fall in the latter class, we believe that multiple draws should be viewed with caution until tested in practice.

Proper Application of Test—One should avoid applying the results of the wedge-draw tests (or of actual cup-drawing experiments for that matter) to types of forming other than pure drawing. Table II (on page 667) should be used as an index of formability only in cases where there is no appreciable amount of stretching under *simple* tension, of flanging, or of rubber-press shrinking. As an example, 24S-O is classed as more form-

able than 2S-O or 3S-O for pure drawing; but if an appreciable amount of flanging and stretching were involved, 2S-O or 3S-O might give better results because of their higher allowable elongations in pure tension.

It is important to note that many parts are formed by a combination of drawing and stretching, and that the relative proportions of these two can be greatly altered by changes in the

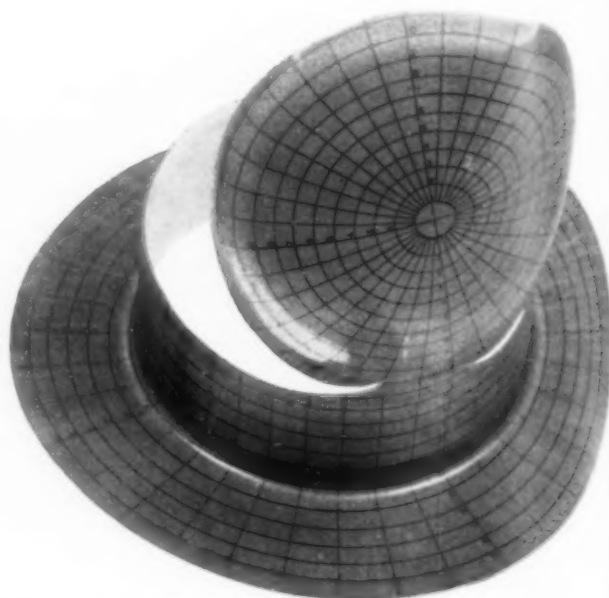
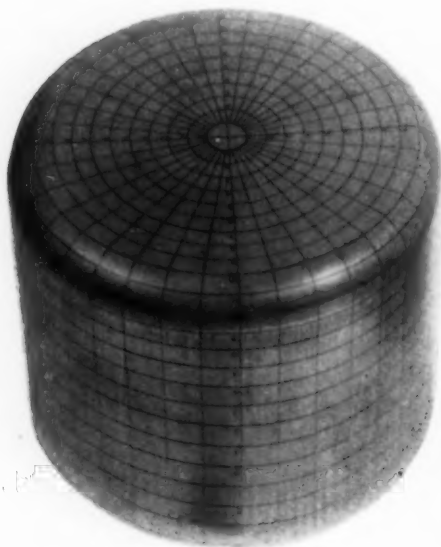


Fig. 6—Two Sheets of 24S-O Were Drawn Into Cups of $r:R = 0.500$. One failed. Wedge-draw tests with $r:R = 0.505$ were cut from the respective sheets; the one shown below drew successfully, the other broke in tension at the neck



hold-down pressure and the blank size. Even for a part which should be formed by pure drawing, as a cylindrical cup, the process may be altered to pure stretching by excessive hold-down pres-

sures which prevent *any* flow of the material under the draw ring. Results will of course be unfavorable because elongations will be limited to those obtainable under tension alone.

Apparent failure of the drawing process may occur, similarly, if an unnecessarily large blank imposes excess tension at the neck of the draw. Substitution of a material having a higher elongation in simple tension, such as 3S-O for 24S-O, or annealed stainless steel instead of $\frac{1}{4}$ H, will apparently have a beneficial effect, whereas the true solution should lie in trimming the blank to correct width. This has been done in practice with considerable success in stainless steel parts, enabling draws to be made from harder material.

Protection Against War Chemicals

General Information Concerning the Characteristics, Effects, and Counteraction of the Agents an Enemy Might Use in War

By Walter P. Burn,
Lt. Col., U. S. Army

NAMES AND SYMBOLS	FORM	ODOR	PHYSIOLOGICAL EFFECT	TACTICAL CLASS	PROTECTION	FIRST AID [After removal from gassed area]	PERSISTENCE	FIELD NEUTRALIZATION
MUSTARD $S(CH_2CH_2)_2Cl_2$ Dichlorethyl sulphide	Liquid and vapor	Garlic, mustard, horseradish	Delayed effect. Burns skin or membrane. Inflammation of respiratory tract leading to pneumonia. Eye irritation, conjunctivitis	Hospital case	Gas mask & protective clothing	Undress; remove liquid mustard with protective ointment, bleach paste, or kerosene; bathe; wash eyes and nose with soda solution	One day to one week; longer if dry or cold	Cover with unslaked lime and earth; 3% solution of Na_2SO_3
LEWISITE $CH_3CH=CHAsCl_2$ Chlorovinyl-dichlorarsine	Liquid and vapor	Geraniums	Burning or irritation of eyes, nasal passages, respiratory tract, skin. Arsenical poison	Hospital case	Gas mask & protective clothing	Undress; remove liquid Lewisite with hydrogen peroxide, lye in glycerine, or kerosene; bathe; wash eyes and nose with soda. Rest and doctor	One day to one week; longer if dry or cold	Wash down with water. Cover with earth. Alcohol. NaOH spray
ETHYLCHLORARSENINE $C_2H_5AsCl_2$	Liquid & vapor or gas	Stinging, like pepper in nose	Causes blisters, sores, paralysis of hands, vomiting. Severe on long exposure	Hospital case	Gas mask & protective clothing	Undress; remove liquid with hydrogen peroxide, lye in glycerine, or kerosene; bathe; wash eyes and nose with soda. Rest and doctor	One hour	Cover with earth, caustic
CHLORINE Cl_2	Gas	Highly pungent	Lung irritant	Hospital case	Gas mask	Remove from gassed area. Keep quiet and warm. Coffee as stimulant	10 minutes	Alkaline solution
CHLOROPICRIN CCl_3NO_2 Nitrochloroform	Gas	Flypaper, anise	Causes severe coughing, crying and vomiting	First-aid; and hospital case	Gas mask	Wash eyes, keep quiet and warm. Do not use bandages	Open 6 hours; woods 12 hours	$NaSO_3$ — sodium sulphite in alcohol solution
DIPHOSGENE $ClCOOC-Cl_2$ Trichloromethyl chloroformate	Gas	Ensilage, acid	Causes coughing. Breathing hurts, eyes water, toxic	Hospital case	Gas mask	Keep quiet and warm. Give coffee as a stimulant	30 minutes	Alkali
PHOSGENE $COCl_2$ Carbonyl chloride	Gas	Musty hay, green corn	Irritation of lungs, occasional vomiting, tears in eyes, doped feeling. Occasionally symptoms delayed; later, collapse, heart failure	Hospital case	Gas mask	Keep quiet and warm; rest in bed. Coffee as a stimulant. Loosen clothing. No alcohol or cigarettes	10 to 30 minutes	Alkali
CHLORACETOPHENONE $C_6H_5CO-CH_2Cl$	Gas	Apple blossoms	Makes eyes smart. Shut tightly. Tears flow. Temporary	First-aid treatment	Gas mask	Wash eyes with cold water or boric-acid solution. Do not bandage. Face wind. For skin, sodium sulphite solution	10 minutes	Strong, hot solution of sodium carbonate
BROMENZYL CYANIDE $C_6H_5CH_2BrCN$	Gas	Sour fruit	Eyes smart, shut, tears flow. Effect lasts some time. Headache	First-aid treatment	Gas mask	Wash eyes with boric acid. Do not bandage	Several days; weeks in winter	Alcoholic sodium hydroxide spray
ADAMSITE $(C_6H_5)_2N-AsCl_2$ Diphenylaminechlorarsine	Gas	Coal smoke	Causes sneezing, sick depressed feeling, headache	First-aid treatment	Gas mask	Keep quiet and warm. Loosen clothing. Reassure. Spray nose with neo-syn-eprin or sniff bleaching powder. Aspirin for headache	10 minutes	Bleaching powder solution
DIPHENYLCHLORARSENINE $(C_6H_5)_2AsCl$	Smoke	Shoe polish	Causes sick feeling and headache	First-aid treatment	Gas mask	Remove to pure air, keep quiet. Sniff chlorine from bleaching-powder bottle	Summer 10 minutes	Bleaching powder solution
HC MIXTURE $Zn + C_2Cl_6$	Smoke	Sharp-acid	Harmless	Smoke	None needed	Produces no effect requiring treatment	While burning	None needed
SULPHUR TRIOXIDE $SO_2 + SO_2HCl$ In chlorosulfonic acid	Smoke	Burning matches	Causes pricking of skin, flow of tears	Smoke	Gas mask	Wash with soda solution	5 to 10 minutes	Alkaline solution
TITANIUM TETRACHLORIDE $TiCl_4$	Smoke	Acid	Harmless	Smoke	None needed	Produces no effect requiring treatment	10 minutes	None needed
WHITE PHOSPHORUS P	Smoke	Burning matches	Burning pieces adhere to skin and clothing	First-aid treatment	None needed	Pack in cloths wet with copper sulphate (blue vitriol) or water or immerse in water. Pick or squeeze out particles. Treat for burn	10 minutes	Burns out
THERMIT $8Al + 3FeO_4$	Incendiary	None	5,000° heat ignites materials	Incendiary	None needed	Treat for severe burn	5 minutes	Quickly cover with dry earth or sand

From Army Ordinance, March-April, 1942.

General Instructions — Protective masks suitable for fire fighting and for mine rescue work are not suitable anti-gas devices. The only masks that are effective against all common war gases are those manufactured according to the Chemical Warfare Service specifications and procurable

through the Office of Civilian Defense. General manufacture and public sale of gas masks is prohibited by War Production Board's General Limitation Order L-57, March 3, 1942.

The importance of proper first aid for gas victims cannot be overemphasized. The following are general rules which apply in all cases.

- Act promptly and quietly; be calm.
- Put a gas mask on the patient if gas is still present or, if he has a mask on, check to see that it is properly adjusted. If a mask is not available, wet a handkerchief or other cloth and have him breathe through it.
- Keep the patient at absolute rest; loosen clothing to facilitate breathing.
- Remove the patient to a gas-free place as soon as possible.
- Summon medical aid promptly; if possible, send the victim to a hospital.
- Do not permit the patient to smoke, as this causes coughing and, hence, exertion.

★ ★ *Conversion* TO WAR PRODUCTION CALLS FOR MORE INFORMATION ABOUT ALLOYS...



★ *Conversion* to war production makes great demands upon both plants and personnel. While altering plant layouts, experienced employees must be taught correct methods of handling new operations on different metals. New employees must be trained...and taught to avoid waste and spoilage of critical materials.

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Heat Treated Rails

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in Great Britain

WHEN THE FIRST British standard specification for bull-head railway rails was issued in 1904, rail steel in Great Britain was still being produced chiefly by the bessemer process, both acid and basic, although a beginning had been made with openhearth steel production. The specified chemical composition was based on bessemer practice, and called for carbon between 0.35 and 0.50%, manganese 0.7 to 1.0%, silicon not to exceed 0.15%, phosphorus 0.075% max. and sulphur 0.080% max. But the rapid extension of openhearth steel production during the 1914-1918 war and afterwards almost completely eliminated bessemer steel in Great Britain. This called for a radical change in rail steel composition, which was effected in a revision of the British standard specification for steel rails dated 1922.

The new specified composition was 0.55 to 0.65% carbon, manganese not to exceed 0.80%, phosphorus 0.04% max., sulphur 0.05% max., and silicon from 0.10 to 0.30% — recognition being thus given to the value of silicon as a deoxidizing agent and for increasing the fluidity of the steel. For bessemer acid rails, still made at one British rail mill of high capacity, the carbon limits were fixed at 0.45 to 0.55%, with a maximum of 0.90% manganese and a relaxation of the sulphur and phosphorus limits to 0.06%

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max. However, experience proved that these changes in the two classes of steel did not have the desired result. Although considerably harder than before, with an accompanying disadvantage of high rolling and finishing temperatures, the rails had an even shorter life than their lower carbon predecessors. This could not be attributed entirely to increases in the weight, speed and density of the traffic; the rails were generally found to have a coarsely crystalline structure in the head that tended to grind and powder away under traffic.

In 1931, the London and North Eastern Railway, after experiments which proved that the arbitrary limitation of manganese to a maximum of 0.80% in openhearth rails had had no small influence on the loss of weight by wear, decided to specify a minimum of 0.90% manganese with an upper limit of 1.10%, later increased to 1.20%. Carbon was reduced by 0.05%, leaving limits of 0.50 to 0.60% in the openhearth basic and 0.40 to 0.50% in the bessemer acid process. Sulphur and phosphorus limits were increased in the former process to 0.06%; it was hoped, indeed, that in addition to the manganese, the slightly increased phosphorus percentage, safely permissible in view of the reduced carbon, might be of some assistance in reducing wear.

Track measurements of these medium manganese rails, in comparison with the previous higher carbon rails, showed an increased life of 25 to 33%. Other British railways followed the lead thus given, and the medium manganese composition was included in a further revision of the British Standard Specification, which became effective in 1935.

In making the change, the London and North Eastern Railway authorities took into consideration some of the problems of manufacture. Rejections of rails for skin defects

would probably be less than previously owing to the healing effect of the increased manganese, while the relaxation of sulphur and phosphorus limits would effect economies in steel making, which together would compensate the manufacturers for the slightly increased quantity of ferromanganese needed. The manufacturers accepted this view, and medium manganese rails of the composition indicated are therefore supplied at the base price for normal carbon rails without supplement.

Controlled Cooling

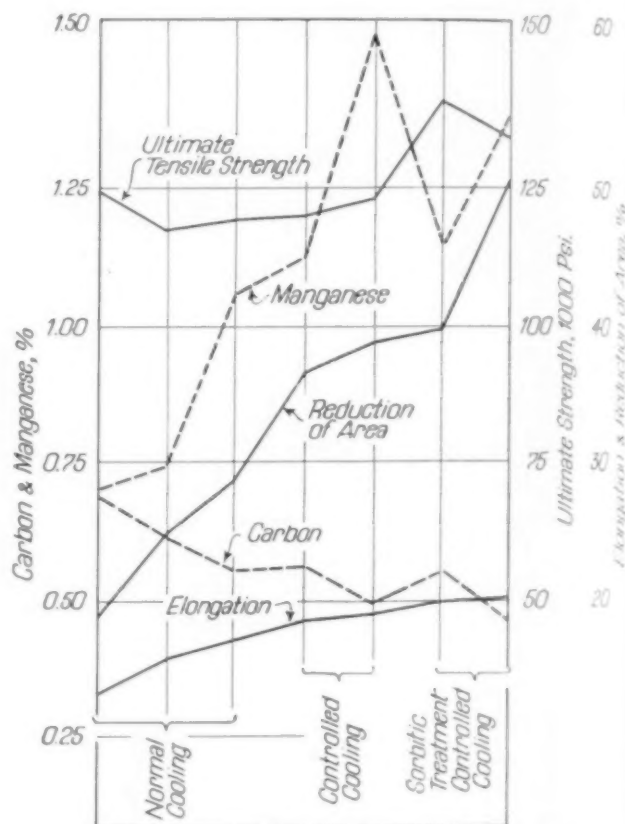
Controlled cooling by the Sandberg process is now done at every rail mill in Great Britain with one minor exception. The cooling ovens are located on the hot beds and certain of them are fixed structures through which the rails are skidded. The latest type of oven, however, is a travelling cover of high insulation efficiency which is moved slowly over the rails as they lie on the hot bed, remaining over them sufficiently long to encompass the range of 1020 down to 570° F. A cover 15 ft. wide, lined on the underside with asbestos sheets placed 13½ in. above the level of the skids, deals simultaneously with 60 rails of the 95 lb. or 100 lb. per yard bull-head section, the rails being ranged head up and in contact with each other as the cover passes over. This method has the double advantage that less handling (and subsequent cold straightening) is needed than when the rails have to be skidded through the oven, and that a movable cover is less of an obstruction on the hot bed than a fixed oven.

As the carbon content in British rails is considerably lower than in American practice, shatter-cracking and the subsequent development of internal fissures have never been a serious menace. Controlled cooling is less a protection against fissures than a definite improvement in the physical properties. This is made apparent in tensile tests by the increased elongation and reduction of area without loss of breaking strength, as compared with rails which have not been subjected to this treatment.

Heat Treatment

An article in the July 1940 issue of METAL PROGRESS, entitled "Steel Rails in the U. S. — A Review of Developments", said: "Attempts to heat treat rails with the object of securing superior physical properties very definitely have

not resulted in a heat treated rail that fills the service and safety requirements." This is contrary to our experience in Great Britain, where another of Sandberg's processes (the "regulated sorbitic process") has secured a firm foothold and in normal conditions is being applied at four English rail mills to over 20,000 tons of rail annually—that is, to perhaps 10% of our annual rail consumption. One plant can treat rails up to 90 ft. long and the others up to 60 ft. The Southern Railway, with the largest suburban electrified railway system in the world and exceptionally dense traffic, takes over 10,000



Improvement in Physical Properties of Rail Steel by (a) Increasing Mn and Reducing C, (b) Controlled Cooling from 1020 to 570° F., (c) Sorbitic Treatment—Spray Quench Followed by Controlled Cool

tons of sorbitic rails every year. It is precisely because the treatment *does* fill both safety and service requirements, and gives an increased life far more than proportionate to the 12½ to 15% added to the first cost of the rails, that its popularity steadily increases.

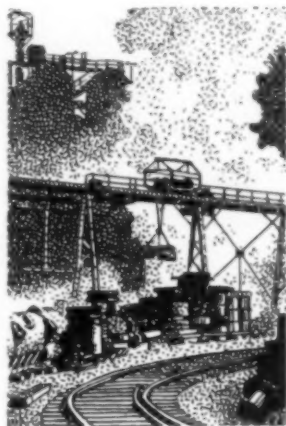
Safety from shatter cracking after a quench is insured by retarded cooling after the sorbitic treatment. In any event the moderate carbon limits of the standard British medium manganese rail give plenty of latitude in treatment

without fear of setting up severe internal stresses in the head of the rail. Control of the sorbitic treatment is now so precise that the range of tensile breaking strength in the treated portion of the rail head can be reduced to narrower limits than in the untreated rails. That is to say, by suitable pyrometric and time control the treatment can be varied to suit the carbon content of each heat of rails brought to the treatment plant, in order to insure a uniform result.

The regulated sorbitic process consists in the application to the rail head, immediately after rolling, of a finely atomized spray of water under pressure. Treatment is begun at between 1560 and 1440° F. according to the carbon content of the heat, the temperature being indicated to the operators by pyrometers and checked as necessary by fusible salts. The rails are skidded one, two, or three at a time to the apparatus (the larger plants being designed to handle 100% of the mill output) turned head upwards, and centered by the skids under the jets. These jets are carried by a girder spanning the width of the hot bed and may be lowered automatically until the distance between jets and rail head is 3½ in. Jets are spaced at 2½-in. intervals from one end to the other, and are so designed that the spray spreads fanwise, thus being applied evenly along the length and full width. For the first portion of the quench, usually about 15 sec., the pressure of water is increased to a head of 20 to 25 ft.; the second stage, lasting from 15 to 30 sec. according to the plant in use, is at a low head of 2 to 2½ ft. only. The change of head is effected automatically by a time clock. The whole operation takes an average of 35 to 40 sec. Immediately following the sorbitic treatment, a cambering plant puts a counter-camber into the rail, thus offsetting the cambering effect of a hard head and a normal base, and reduces the amount of cold straightening necessary. After this the rail is passed at the appropriate temperature to the oven for controlled cooling.

It is an indication of the safety of the sorbitic treatment that the drop tests applied to the treated rails are more severe than the standard tests on ordinary rails. From every heat one treated rail and one untreated rail are

tested alike—a 5-ft. length rests on supports 3 ft. 6 in. apart, and is hit by a falling weight of 2240 lb.—but in addition to the customary blows from 7 ft. and 20 ft. in succession given to untreated rails of the 95 lb. and 100 lb. per yard sections, treated rail test pieces are subjected at most plants to an additional 20-ft. blow. The treated rails also are tested base up (head in tension) to demonstrate that no shatter cracking or excessive stresses are present in the heat treated head.



Tensile tests are made on the treated steel at frequent intervals and it is from these that the beneficial effect can best be assessed. Tests are taken from the head ¾ in. below the running surface. As they are standard "C" type (0.564-in. diameter to give an area of 0.25 sq.in.) the steel is being tested to a depth of slightly more than ⅝ in. below the running surface—that is, to the maximum depth to which

the rail will be allowed to wear down in service. Characteristically the breaking strength rises as a result of treatment by an average of over 20,000 psi., and the yield point goes up in considerably greater proportion. The average of a large number of recent tests showed that the yield point (61½% of the ultimate strength in the untreated rails) had risen to 83½% of the ultimate strength in the treated rails. Percentage elongation is generally slightly reduced by the treatment, but the reduction of area at the point of fracture is increased—an indication that despite the greatly increased hardness of the steel, its toughness has been in no way impaired by the heat treatment, but has rather been substantially increased.

The graphs which are reproduced are based on the results of analyses and tests made in the course of recent contracts for rails for the London and North Eastern Railway, and so far from being fortuitously good results obtained on individual heats, are average results obtained on considerable tonnages of rails, and so are fully representative of normal practice.

The first figure shows the effect of increasing the manganese content, while at the same time reducing carbon, and then of adding either controlled cooling or the sorbitic treatment. Note the steady increase in elongation and reduction of area, with a simultaneous gradual rise in the ultimate strength. Such average

Hardness Averages, Illustrating Depth of Penetration of Sorbitic Treatment Into Rail Head

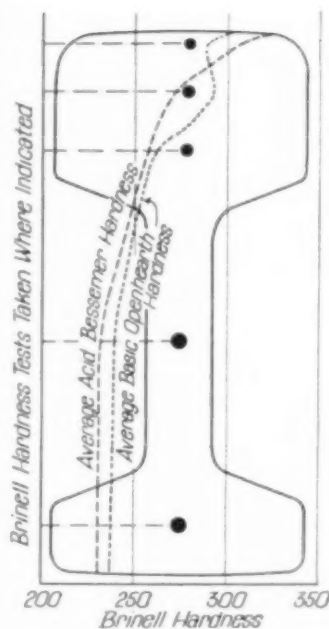
figures as 19.7% elongation (measured on a 2-in. gage length) and 39.7% reduction of area with an average ultimate strength of 140,670 psi. for sorbitic medium manganese rails are remarkable. No less noteworthy is the 20.0% elongation and 50.4% reduction of area with 134,000 psi. ultimate strength in sorbitic rails with somewhat higher manganese (1.39%). It will also be noted that the substitution of a medium manganese composition, with reduced carbon, for the previous higher carbon composition gave an immediate improvement in elongation and reduction with very little reduction in strength, and that the addition of controlled cooling effected a further appreciable improvement.

The second figure illustrates the penetration of the treatment and shows average Brinell readings on the running surface of the rails and at points $\frac{1}{8}$ in. down, $\frac{5}{8}$ in. down (center of head), $1\frac{1}{4}$ in. down (base of head), in the center of the web and in the foot. From this diagram the even transition from the hardened to the unhardened zone is evident; this is made even more clear in the large diagram with micros, referred to later. Brinell hardness readings up to 400 have been obtained experimentally on the running surface of rails by the sorbitic treatment, but these are rather more extreme than the normal hardness sought.

End Batter

Battering of rail ends is not a serious problem in Great Britain, and ends are therefore not hardened. It would be a relatively simple matter by adjusting the sprays in the Sandberg sorbitic plants to increase the hardness at the ends in a single quenching operation.

In 1931 research was

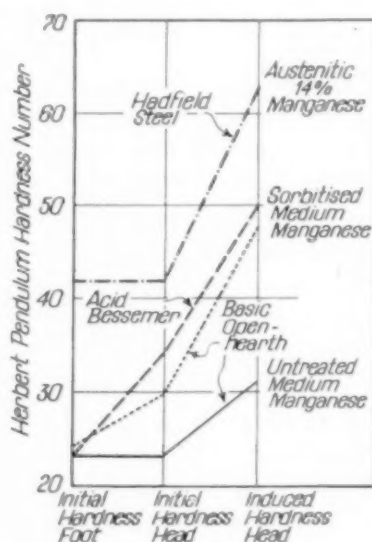


directed by the London and North Eastern Railway into the composition and physical properties of certain rails manufactured in the early days of steel making, which had remained in continuous service for 40 to 50 years in other than first class main line tracks. These rails were of 80 and 82-lb. sections (see the last figure); some of them during this long period had lost only $6\frac{1}{2}$ to $8\frac{1}{2}$ lb. per yd. in weight by wear. In some respects the chemical composition was extreme; sulphur, for example, was high, in one rail being up to 0.122%, but carbon generally was low, in two rails not exceeding 0.320 and 0.325%.

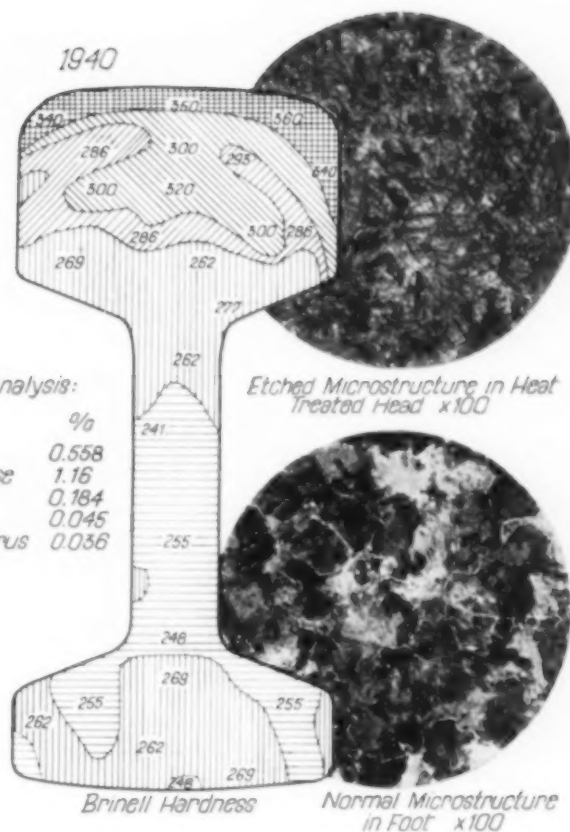
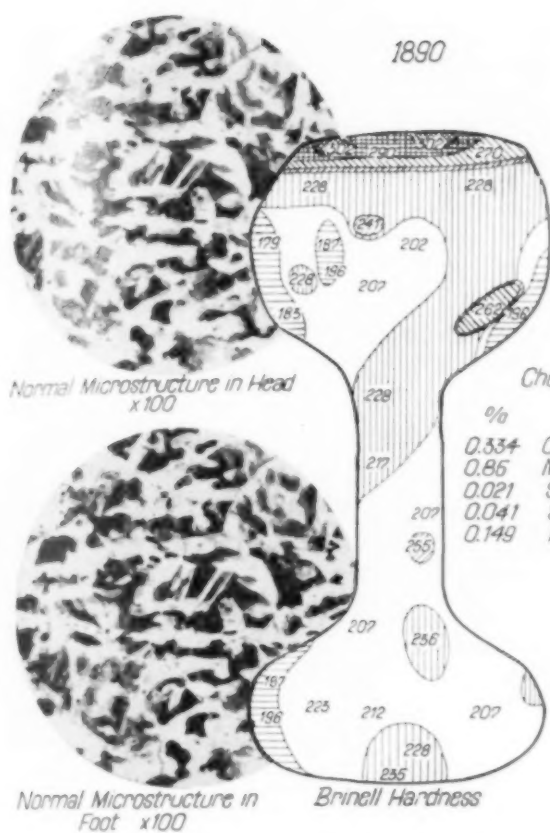
The conclusion reached in this research was that the wearing capacity of these early rails was sufficiently in advance of the traffic conditions of their time to allow the running surfaces to work harden slowly, thus providing them with a tough protective skin which has stood them in good stead in their later years. If it were possible to produce a rail equally in advance of present-day traffic conditions and capable of work hardening under traffic, an important step would have been taken towards reducing the frequency of rail replacements in main lines.

The rail which best fulfills these conditions is, we believe, the alloy containing from 12 to 14% of manganese, invented and first produced by the late Sir ROBERT HADFIELD, but our experience indicates that its extremely high initial cost is only justified where wear is unusually severe. Owing to the uncertain properties of

the chromium alloy rail, this also has found no extensive use on British railways. But the sorbitic rail, at a relatively small additional cost of production, possesses this work hardening property. This has been shown by the Herbert pendulum hardness test, which measures the initial hardness of a metal specimen, and then the hardness induced as a result of cold working it.



Work Hardening Capacity of British Rail Steels, as Indicated by the Herbert Pendulum Hardness Tester



Chemical Analysis:

%		%
0.334	Carbon	0.558
0.86	Manganese	1.16
0.021	Silicon	0.184
0.041	Sulphur	0.045
0.149	Phosphorus	0.036

Fifty Years Progress in British Steel Rails. Cross hatched areas showing equal hardness may use-

fully be replaced by a color code, showing at a glance the peaks, contours and valleys of hardness

In some recent Herbert tests on sorbitic rails, summarized in the small graph at the bottom of page 674, an openhearth basic rail, which had an initial hardness of 24 on the untreated foot, had been quench hardened to 30 on the treated head, while the head hardness induced by cold work was 48—a total gain of 100% over the untreated state. A bessemer acid rail, with an initial hardness of 23 on the foot, went up to 34 by heat treatment, and the induced hardness on the treated head was 50—a total gain of 117%. The excellent wearing capacity of the modern sorbitic rail is thereby in part at least explained; and the improvements brought about in the ordinary rails by the increased use of manganese and controlled cooling—of which increased elongation and reduction of area in the tensile test give valuable indications—are in the same direction of increasing the work hardening capacity.

Rail Lengths and Sections

In the matter of rail length considerable progress has been made in Great Britain. Early in the present century the London and North Western Railway which then had its own steel

plant at Crewe Locomotive Works and rolled its own rails, introduced and standardized the 60-ft. rail. This has now become the general rail length, and is supplied by all British manufacturers at the base price for rails without extra, mill layouts having been altered as necessary for handling long rails. The London and North Eastern Railway has gone further, and for important main line locations is using rails 90 ft. long; the elimination of joints and the reduction in maintenance costs—in addition to the smoother ride—are advantages regarded as sufficient justification for the additional production and installation cost.

Experimentally, 120-ft. rails have been produced without welding by two British mills and laid in main lines; problems in handling, transporting and laying rails of this great length were successfully overcome, but experience tends to show that 90 ft. may be regarded as the maximum economic length, and this is not likely to be exceeded, except by welding. In the latter direction much has been done, chiefly by the Southern Railway and the London Passenger Transport Board, in producing 180, 240, and 300-ft. rails from 60-ft. lengths, both the electric flash-butt and the thermit (Cont. on page 694)

By Harry J. Sweeney
Chief Metallurgist
Youngstown District
Republic Steel Corp.

Record Tonnages from American Openhearth

MORE TONNAGE, regardless of cost! This was the keynote of the openhearth steel makers at the important 25th meeting of the Openhearth and Blast Furnace Conference of the Iron and Steel Division, American Institute of Mining & Metallurgical Engineers, held at Cincinnati last month. Both large and small steel companies were well represented by their best technicians and a thorough transfer of ideas about new developments resulted. LEO F. REINARTZ, general chairman, again proved to be an excellent ring master for a three-ring performance.

A unique quality of the meeting was the absence of the usual questions and arguments about costs. The steel makers clearly indicated that they wanted more tonnage, and more tonnage *now*, no matter what the cost. Even realizing that the grouping of orders on the rolling mills, along with other factors, had thrown the ingot production out of balance with the finishing capacity, still the openhearth operator stressed the need of increased ingot output in order to fill the requirements of the mills. Sufficient hot metal will permit this condition as soon as new blast furnaces can be brought into production, but the industry is not satisfied to wait for this. Hence a thorough discussion of methods of reducing ore to iron in the openhearth was in order. Also looking forward to

the time when new iron capacity would necessitate high metal charges, the committee presented a program to familiarize all concerned with the handling of this type of charge. Charge ores were discussed and information was freely offered by several companies who have spent considerable time in preparing the available ores for more suitable use.

Items pertaining to increased furnace output, faster repairs and fewer delays also were considered from the viewpoint of getting the most from our present equipment.

As to strategic materials, an entire session was devoted to conservation of essential alloys and refractories, with supplementary information as to available substitutes.

High Metal Charges — In view of an abundance of pig iron in the near future, much interest was expressed in furnace operation with high metal charges. Plants having sufficient iron to charge their openhearth with 65 to 75% iron (metallics in ore included in this proportion) are usually self-contained so far as any need of outside scrap is concerned. Several plants in the country are practically now in this position although the industry as a whole is far below it. However, looking forward to the time when high metal charges will be the order of the day, most plants have experimented with this type of heat. The general opinions expressed as to the best methods follow.

The limestone is charged on the bottom of the furnace, some plants using a small amount of light scrap between the furnace bottom and the stone. The stone must be evenly spread over the bottom so piles will not stick up high into the charge, or be placed too far up on the shallow ends of the hearth. In flush heats it is important to keep the lime out of the liquid system until the flush is completed, otherwise the flush slag is too thick to run conveniently

and what slag is flushed carries off with it excessive lime. Charging too much lime also makes it difficult to keep it out of the system so that a maximum amount must be agreed upon. Most operators believe that a maximum of 5% limestone charge will permit a flush sufficient to remove a desired amount of the silica and phosphorus from the furnace. A low volume of tap slag is important on high metal charges if high tonnage rates are to be maintained, and it follows that good flushes are also essential to meet these conditions.

The ore is charged directly on the limestone in such a way as to cover the stone completely. Proper ore is necessary for successful operation of high metal charges, so charge ores were discussed and may be grouped as follows: Mesaba soft ores, lump ores, sinter, dried soft ores, and nodulized soft ore.

The Mesaba soft ores were studied with respect to three conditions, (a) ignition loss (per cent of combined water), (b) silica content and (c) degree of fineness. When any one of these factors, except the silica, becomes excessive, the heat will "blow" when hot metal is run into the furnace, with resulting loss in heat time, damage to furnace, and danger to operators. It was pointed out that a maximum of about 7 lb. of H_2O , as water of crystallization, per ton of ingots, could be introduced in the soft ore before excessive blowing took place. Some few plants were able to allow as much as 10 lb. of water by sandwiching the ore between layers of scrap. This illustrates the importance of using ore with low ignition loss where high metal charges are to be made. Water of crystallization is not driven off most soft ores under $900^\circ F$. The degree of fineness of an ore has some effect upon "blowing", but the exact influence has not been accurately determined as yet. The part that silica in an ore plays is to increase slag volume. As previously stated, good tonnages come from high metal charges when the tap slag volume is kept low. Hence high silica ores will increase the slag volume and it was the consensus that the introduction of a maximum of 15 lb. of silica from the ore per ton of ingots was the point where the resulting decrease in tonnage counterbalanced the gain in metal from that particular ore.

To summarize, then, it was agreed that with soft ores having a maximum of 3% ignition loss and a maximum of 7% silica, most plants could safely operate at around 61% hot metal, using between 200 to 270 lb. of ore per ton of

ingots. Above 5% ignition loss in the ore, hot metal appeared to be limited to around 55%.

Any metal charges higher than those just mentioned must have a charge consisting of the maximum of soft ore that it is practical to use and an additional charge of some "non-blowing" material.

Realizing the limits set by soft ore on the amount of hot metal that could be used it was next in order to look for substitutes to make up this additional charge. Sinter has been used extensively and where it is of a dense nature it works quite well. Port Henry sinter (magnetite ore) has been used very successfully on 80% metal charges. Sinter for charging into a blast furnace is intentionally made very porous, but openhearth sinter, because of the limited space in the bottom and the desired reaction rate, must be dense. This dense type of sinter has been produced by using 10% roll scale, some limestone, increased fuel, and 50 in. of water draft on the sintering pan. (Ordinary sintering plant drafts are around 15 in. of water.)

Lump ore, although admittedly ideal for charging, was not discussed because of its scarcity. One company was briquetting soft ore by adding 1% of portland cement, mixing, packing in a jarring machine and drying.

Nodulized Soft Ore

Of great promise appeared the recent plan of nodulizing soft ore in a rotary cement kiln, using powdered coal for fuel. Limestone screenings (8%) are mixed with the ore and the resulting product is dense granules up to walnut size with little or no fines. The final product of course contains 4% CaO which no doubt helps in the fluxing. This nodulized ore is the equivalent of the best sinter and probably does not rank far behind lump ore as a charge material. At present, it is being made in large quantities in the Pittsburgh district and can be considered beyond the experimental stage. Steel companies that will have to face high metal charges in the future without suitable charge material will find this nodulized material a life saver.

To continue with the charging of high metal heats: The ore is placed uniformly over the stone and the scrap added as rapidly as possible. (Operators have dried the soft ore by running the furnace a half hour or so before charging the scrap, but the ore glazes over and little water is driven off.) The scrap is brought up to at least the temperature of the hot metal and



Character Study of Openhearth Melter; by Eugene Hutchinson for Colorado Fuel & Iron Co.

the latter then added, also as rapidly as crane service permits. The slag foams up shortly after the addition of the metal, and should be flushed off the heat as soon and as thoroughly as possible. The matter of flush holes is of extreme importance and most plants will have to revise their present equipment drastically if sufficient slag is to be removed from 65 and 70% metal heats. An ideal condition was reported by one Cleveland operator during the making of a 100% metal heat. He flushed out of the back and front of the furnace; the back flush was through the conventional hole in the back-wall and the front flush was out the middle door into a thimble mounted on a truck between the fantails. The small amount of limestone used on this heat, some 6%, is a tribute to the excellent job of flushing. Present furnaces with sloping backwalls will find it difficult to maintain the present type of flush-hole in a suitable condition to handle the large amount of flush slag. Probably a door could be installed at the back flush spout so that an opening some 2 ft. across and flat on the bottom could be maintained.

After the flush has been completed, the high metal heat is worked in the conventional manner, although slag should be controlled by the use of slag cakes. High metal flush heats will require more slag adjustments than scrap heats because of variations in the amount of flush from heat to heat.

Reduction of Ore in the Furnace

Because of the present shortage of scrap and metal for our steel furnaces, it was strongly urged that all operators thoroughly study the possibilities of reducing more ore in the openhearth. It was pointed out that if we could obtain only 2% more metallics from ore without delaying the heat, our ingot output could be increased by 1,800,000 tons this year! The importance and need of this tonnage now as compared to some future date makes it a duty of all concerned to strive for this goal regardless of cost, trouble or effort.

Methods used towards this end have been as follows:

1. Carbonaceous material has been charged with the ore and the ore charge increased. Loss in yield and tonnage has been experienced by most operators attempting this method, but experimentation is continuing along this line.
2. Cutting the limestone charge is another method and offers concrete results. Limestone imparts considerable oxygen to the bath as the CO_2 from calcination breaks up into CO and O. Replacing this oxygen by oxygen from the increased ore charge results in an increase of metallic output from the ore. Some operators have had excellent results with a 3% limestone charge, making up the deficiency of lime with a burnt lime addition immediately after the flush.
3. A third method is the use of all burnt lime in the charge. Extreme care is necessary to keep it out of the system until after the flush is completed.

At the risk of repetition it must be again pointed out that one of the most important jobs facing the operator today is that of obtaining more metallics from ore in the openhearth.

In this same connection, we find the bessemer operator using ore to cool the blow in place of pig iron or scrap. This has resulted in at least a 2½% increase of metallics from this source and some operators expressed the belief that by careful control of air volume at the early stages of the blow they could increase the figure to 5%.

Duplexing with Blown Metal

Where molten iron is available, the fast converting operation of the acid bessemer may be used to advantage for increasing steel production. One plant reports a 40 to 50% increase in openhearth output by using a charge of 20% scrap and 80% blown metal, the latter from two 25-ton acid converters, one located at each end of the openhearth floor. A 5% limestone charge is used in the furnaces and the resulting lime boil apparently solves the nitrogen question so prevalent in discussions of bessemer steel. Steel from the above plant is satisfactory in all products formerly made by conventional means.

Duplex steel from tilting furnaces was also thoroughly discussed—principally the huge tonnages made by this process and the uniformity of quality.

Right now the above two methods offer one disadvantage in that they reduce no ore and hence this source of metallics is lost.

Alloy Materials

Concern was expressed over the alloy situation. Without going into a detailed statement of expected supply, stock-piles and anticipated need, it is apparent that the problem on which the openhearth operator can exert the most influence is on the proper segregation of scrap so that vital alloys are not wasted as useless residuals. The remark was made that we are wasting as much alloys in this manner as the Germans have for their entire steel industry! One operator reported that before one heat of carbon-molybdenum steel could be produced, five heats were diverted (sweetened with additional alloy) because of the high nickel residual in the melt-down. Proper segregation of all grades of scrap both in the consumers' and producers' plants is necessary to correct this.

Steel producers are working extensively on the problem of segregating incoming scrap. Many plants are spark testing unknown purchased scrap, piece by piece, and recovering large quantities of alloys in this manner. Rapid chemical spot testing is also entering the picture.

Conservation of manganese was discussed at length, more or less following the lines of the article on page 647 of this issue of METAL PROGRESS. It was generally felt that the producer was doing about everything possible towards this end. The steel producer has control over the analysis of about half of the

nation's steel output, and manganese in these steels has been cut to the very bottom. Ladle additions have been resorted to whenever possible in preference to the less efficient furnace additions. High manganese steel scrap is segregated and used in the furnace as a ferro-manganese addition. Average analyses of heats made by each melter foreman are regularly checked to find out whether some individual is continually playing to the "high side".

In 1941 the industry used 12.5 lb. of ferro-manganese per ton of ingots produced. This same figure held good in February 1942, in spite of the fact that a large number of the low manganese grades of steel such as automobile sheets have been discontinued, and that the production of higher manganese steels (particularly sulphur bearing steels) has increased. This clearly indicates a good job is being done on the conservation of manganese. However, the half of the steel produced whose analysis is governed by the consumer may bear scrutiny.

Aluminum consumption has decreased from 0.7 lb. in 1940 to 0.54 lb. per ton of ingots at the present time. Operators have gone to mold additions whenever possible. Small ladle additions were discussed as to their usefulness. Substitutes were considered, and some borax compounds were reported as giving equal results to aluminum when used on rimmed steels.

The Scrap Problem

Faced with a serious scrap shortage, the operators exchanged views regarding the accumulation and recovery of scrap. Old refuse dumps throughout the country are being extensively mined for scrap metal. Larger pieces of metal recovered in this manner are cleaned of slag by tumbling or by treatment at the high drop and charged directly into the openhearth. Smaller pieces of metal are collected magnetically and cleaned by tumbling. These are usually returned through the blast furnace.

Plants are periodically surveyed and useless spares cut up for charging. Old buildings have also yielded considerable tonnage for reconversion into ingots.

The matter of tinned scrap appears to present the most serious problem. Some grades of steel will absorb considerable tin without damage to the final product, but others prove very sensitive to even a few thousandths of one per cent. Operators felt that they could handle tinned scrap if it was properly (*Cont. on p. 734*)

Correspondence

from home and abroad

No Shortage in Tungsten Carbide

DETROIT, MICH.

To the Readers of METAL PROGRESS:

At a meeting of the Senate Committee on April 16, considering whether the present law concerning patents is a help or a hindrance to the national effort, Mr. LEWIN (who is acting as "official prosecutor") presented a long dissertation on tungsten carbide containing accusations in the form of inferences and conclusions which have no foundation. He stated that there is a scarcity of tungsten carbide. There is no scarcity and there has never been any. Carboloy Co., Inc., has been able to take care of every United States order—and in addition has also been supplying England and Russia since 1939.

It is asserted that we maintained artificially high prices even though during the period in question the Carboloy Co. made six price reductions, and in spite of the fact that it was continuously operating in the red.

It is inferred that General Electric and Carboloy restricted or is restricting production of this material and is, thereby, slowing up the war effort. This is not true. In 1938 the facts show that there were some 97 manufacturers of Carboloy tools in the United States and at no time were all carbide manufacturers under license or price control. As far as the present patent relationship with Krupp is concerned, there just isn't any. Anybody can make carbides.

It was because General Electric appreciated

the possibilities of tungsten carbide and secured ownership of the vital patents then owned by Krupp that the Government and war industries can now obtain all the carbides they need.

If we had not done so, the United States would have been at the mercy of German sources of supply just as England was at the outbreak of the war. Fortunately, Carboloy had the production capacity at that time—and still has—to ship enormous quantities of carbides to England, in addition to meeting United States requirements.

For years Carboloy and General Electric have been working closely with the War Department and government arsenals. For years there have been available machine tools designed to employ these fast-cutting carbide tools to the machine. For years, the Carboloy Co. has been carrying on an effective and widespread educational campaign on the use of these tools. In one two-year period, long before the war, some 10,000 men in industry were given such training courses.

These are all facts which are well known. In the light of this, it is hard to understand the reason behind the constant reiteration of false public accusations which get wide publicity.

We are engaged in an all-out war effort. The time and effort of every individual should be vitally concerned only with this. It is hard for a man to keep doing his best when he or the company he works for is constantly being unfairly attacked. Isn't it about time we ceased bickering and fighting among ourselves? Isn't it about time we stopped trying to break down our own morale?

W. G. ROBBINS
President, Carboloy Co., Inc.

EDITOR'S NOTE — An accurate statement concerning the early development of cemented carbide tools was printed by RICHARD T. F. HARDING, business columnist for *The Cleveland Plain Dealer*, shortly after the Senate Committee's hearing above referred to, from which we quote:

"The tungsten carbide case is neither more nor less than another instance of international trade in patent rights. That the trust busting department has been moving against such trading

on the ground that it is contrary to the Sherman law is interesting rather than convincing.

"Any sincere investigation of cemented tungsten carbide or of a company engaged in its manufacture would look early into the purposes and methods of its use. But before that, because in international business the question is fundamental, it would inquire where, when and by whom it was invented or developed.

"It was unfortunate that the Senate committee did not ask that question. If it had done so it would have learned that the invention was made in Germany, that most of the early development was carried on there, and that but for the international business connections of General Electric and its lamp department, which enabled it to buy the major share of the American patent rights, this country would have known of the material only as an important German secret.

"It was a shortage of industrial diamonds, one of the results of the blockade in the former World War, that turned German attention to tungsten carbide. The chemical compound had been known, for 40 years or more, as one of a high degree of hardness, but of little use because no one had been able to harness it. A metallurgist named Baumhauer, in the research department of the Osram Lamp Works of Berlin, melted some of it and tried to cast it as a die for drawing fine lamp filaments of tungsten wire, a job that previously could only be done with diamond dies. The casting was porous as a sponge, therefore impractical. Presently it occurred to him to fill the pores with soft iron, a means by which he produced a fairly workable substitute for diamonds.

"Karl Schroeter of the same organization, after many experiments, hit upon milling powdered cobalt with powdered tungsten carbide, pressing the mixture into the desired shape, then sintering it. The relatively soft cobalt, which had coated the hard particles of carbide, was further softened by the heat, with the result that it oozed sufficiently to bind the particles firmly. The mass is so hard that only a diamond will cut it.

"From successful substitution for diamond dies it was only a short step to using the new material for diamond inserts in lathe tools for cutting bakelite and porcelain—also everyday occurrences in an incandescent lamp works. Krupp's research department had been so closely associated with Schroeter's work that the big company was enabled to share in the invention so far as it competed with toolsteels. In 1927 it exhibited some of the new product at the Leipzig Fair. A year later General Electric exhibited it at the convention of the American Society for Metals. Then, or shortly afterward, it was announced that Krupp had licensed three American manufacturers to produce under the patents.

"Because of differences in shop practices we use the material much more sparingly than do the Germans. In this country a small fraction of an ounce of it will be brazed or cemented in place as the cutting edge of an implement otherwise made of steel. The German uses a larger nib."

Martin Seyt Redivivus

ENILOM, USONIA

To the Readers of METAL PROGRESS:

I was thrilled to note, in the new METAL PROGRESS, that MARTIN SEYT has escaped from Rotterdam where he was when last heard from (Sept. 1940) and is with the staff of Plumbine Smelting Co. A story of his transportation or transformation should be a feature of an early issue. No doubt, his escapades included night-riding in a (Roberts) Austin. But perhaps he flew in a cleavage plane. I troost his experiences did not affect his temper; for a long time I feared he had suffered dispersion at Random.

METALLURGICUS

Beware of Lead Containers

PITTSBURGH, PA.

To the Readers of METAL PROGRESS:

Recent press reports that materials such as tooth paste can be kept in collapsible tubes made from lead without becoming contaminated are not true. The press drew this conclusion from a paper presented at a recent meeting of the American Institute of Mining and Metallurgical Engineers under the authorship of myself and Messrs. MARKUS and GROBE. This paper demonstrated that in carbonate solutions in the pH range from 9.5 to 11.2 the tin-lead couple is under cathodic control and the anodic elements are tin. The effect of several addition agents was also demonstrated. The experiments did *not* deal with any commercial material such as tooth paste or shaving cream, and the corrosion properties of lead alone were not discussed. There is of course no scientific justification for applying the results obtained for the lead-tin couple in carbonate solutions to uncoupled lead in any other environment.

In order to avoid cases of lead contamination, it is important that these facts should be disseminated as widely as possible by scientists qualified to understand their implications.

GERHARD DERGE

Metals Research Laboratory
Carnegie Institute of Technology

Confusion in Testing Terms

MASSILLON, OHIO

To the Readers of METAL PROGRESS:

Errors in the diagram on page 201 in the February issue are the best possible substantiation of the title of the article! It was intended to show the location of various points as defined by existing terminology, and should therefore appear as Fig. 1, herewith.

To this may usefully be added a new diagram (Fig. 2 at the bottom of the page) showing the positions as denoted by the proposed new terminology.

It would also be more in conformity with the author's ideas to word the second paragraph on page 202 as follows:

"The use of the term 'yield' should be discouraged in any other connotation than the yield of a soft steel which occurs shortly beyond the limit of proportionality."

GEORGE P. LENZ, JR.
Metallurgical Dept.
Union Drawn Steel Division
Republic Steel Corp.

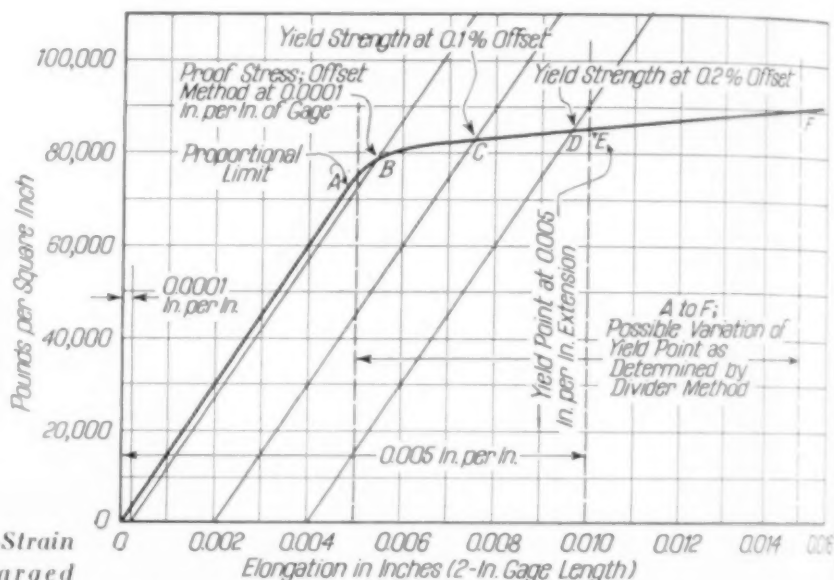


Fig. 1—A Typical Stress-Strain Diagram, With an Enlarged Horizontal Scale, for Cold Drawn Steel, Stress Annealed, Showing How Values in the Region Between Elastic Action and Plastic Flow Are Defined in Existing Specifications

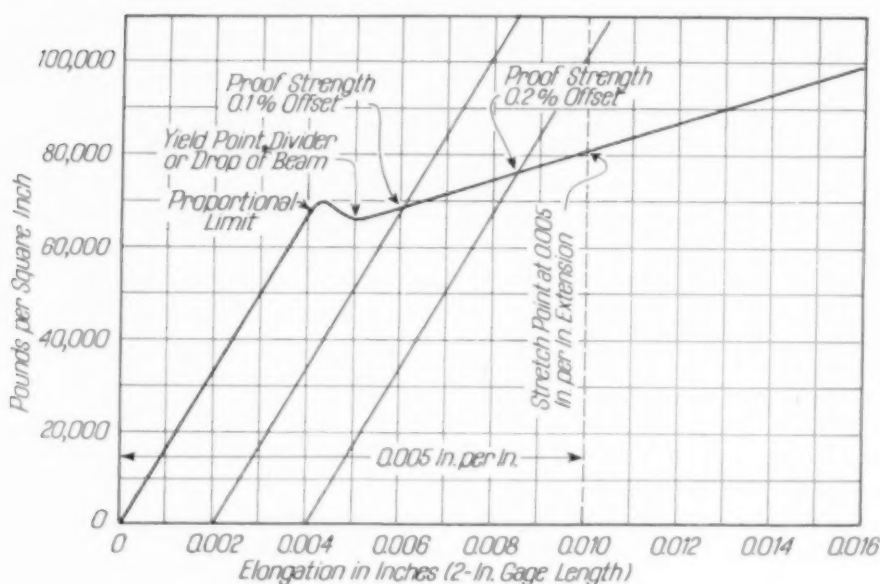


Fig. 2—Stress-Strain Diagram for Soft Steel, Showing Positions of Points According to Proposed New Terminology

Effect of the Nature of Inclusions on the Metallic Structure

UGINE, SAVOIE, FRANCE

To the Readers of METAL PROGRESS:

The great influence of solid particles on the crystallization of solutions and the solidification of molten mixtures and alloys is well known; by acting as a nucleus or artificial center of crystallization, each tiny particle induces such crystallization by preventing supercooling of the liquid at that point.

This action depends on the nature of the

tiny non-metallic particles. Isomorphism with the crystal to be formed has a well-known and important influence; doubtless also *l'épitaxie*, that is to say, the phenomena of mutual orientation of crystals of different species and nature. Isomorphism and epitaxis offer to the atoms about to be precipitated the exact or approximate model of the crystalline structure to be realized. An example is given in the experiments of TAMMANN and BÉKIER on the crystallization of ice. Solid particles are not absolutely necessary; even gaseous bubbles can act as centers of crystallization, as in the case of silicates.

These phenomena are of particular importance when there are two crystalline forms of different stability which might appear on solidification. The most important example of this is cast iron, in which either graphite, the stable form, can solidify and thus make the gray cast irons, or carbon can combine with iron and appear as cementite, the metastable form, in white cast irons. As we have already pointed out, in a letter entitled "Estimation of Inclusions" in METAL PROGRESS for July 1939, this explains certain aspects of oxidation, of slags, and of treatments in the liquid state affecting the graphitization of castings on solidification.

This influence of foreign particles can be seen even in transformations in the solid state when new constituents or crystalline phases are formed; non-metallic particles or inclusions then play an analogous role.

Likewise the effect of certain inclusions on the formation of pro-eutectoid ferrite in hypoeutectoid steels has been observed; that is, the mass or alignment of inclusions causes accumulations or bands of ferrite forming what is known as ghosts or banded microstructure. This effect has been interpreted as the result either of a chemical action, whereby the metal is decarburized around the oxidized inclusions or, as has just been pointed out, the result of a physical action, wherein the inclusion acts as a center of crystallization for the ferrite. Since inclusions can have the same effect on pro-eutectoid cementite or iron carbide, and since sulphides can also act in the same way, it would appear that the second interpretation is the better one.

Small additions of aluminum to molten steel containing some oxygen give inclusions of alumina. Influence of such particles on the size of the austenitic grain which appears on heating through the A_3 transformation can be explained in an analogous manner.

(Continued on page 738)

Automatic Tube Welder

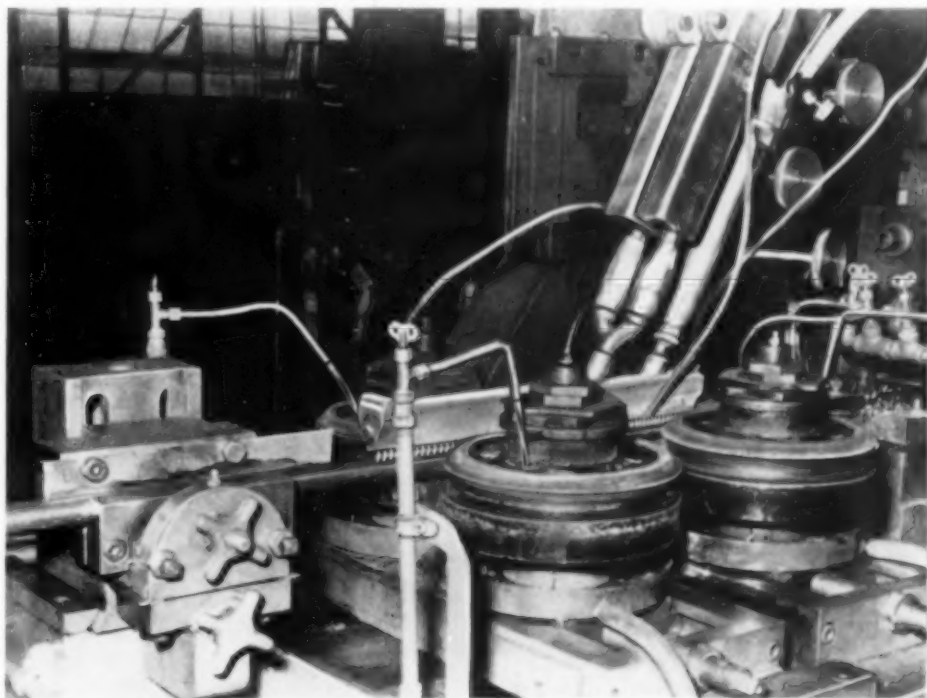
NEW YORK CITY

To the Readers of METAL PROGRESS:

A high speed tube welding machine, containing many new features, has recently been put in operation by the Yoder Co. of Cleveland, as the result of extensive experimentation and development by that company in association with Linde Air Products Co. Raw material is thin strip in large coils. This is fed endwise through a nest of forming rolls, quite similar to those in use on other tube welding equipment.

The welding section of the machine shown in the accompanying view contains several new features making for high speed. Heat is supplied from a new multiple-flame, duplex welding head which requires 25% less acetylene and 10% less oxygen per foot of weld than equipment previously used. Separate gas lines lead to the welding and the preheat flames, and the supply is automatically controlled (electrically and pneumatically) through new-type regulators which are extremely sensitive and steady. Regulator adjustments are made at a dial on a conveniently located control panel, which also contains a push-button control for the drive mechanism.

As the edges of the abutting seam are



Welding Head on Tube Machine, Showing Double Line of Small Flames Preheating and Bringing the Abutting Edges to Welding Heat. Passage of tube is from left to right

heated, the tube is pressed sidewise by two pairs of water-cooled rolls shown clearly in the view. Passing on (toward the right of the view) the welded tubing goes through a water quench trough and then through a set of straightening rolls before it is cut into correct lengths by a flying shear.

From operations so far observed the following advantages may fairly be claimed for the new machine:

1. *Rapid Rates of Production.* Satisfactory tube has been made in common steel strip within the following range of speeds, in feet per minute:

14 gage	30 to 100 ft.
16 gage	40 to 140 ft.
18 gage	60 to 150 ft.
20 gage	Up to 100 ft.

The last value is limited by mechanical facilities now readily available for handling light-weight strip.

2. *Unpickled Steel Can Be Welded.* All that is necessary to produce quality tubing from hot rolled stock is a slight increase in oxygen and acetylene. There is a considerable demand for this type of material for low-cost items such as conduit, and structural tubing on which a smooth or polished finish is unnecessary.

3. *Versatility.* In addition to plain carbon steels, cold rolled or hot rolled, and stainless steel strip, this new welding machine will successfully handle a wide variety of alloy steels. Since one of them can turn out over 12,000,000 ft. of tubing per year, the additional versatility of the unit enables the manufacturer to spread his depreciation cost over a larger variety and a larger volume of products with resulting lower costs for each.

4. *Speed.* Since the oxy-acetylene weld is continuous, the only limit to the welding rate is that imposed by such mechanical factors as those of bringing up and feeding coils of strip, and cutting off and handling the finished material. Consequently, it is reasonable to assume that further developments on these handling factors will eventually bring about even greater speeds than tabulated above.

ALAN KELLOCK
Publicity Department
The Linde Air Products Co.

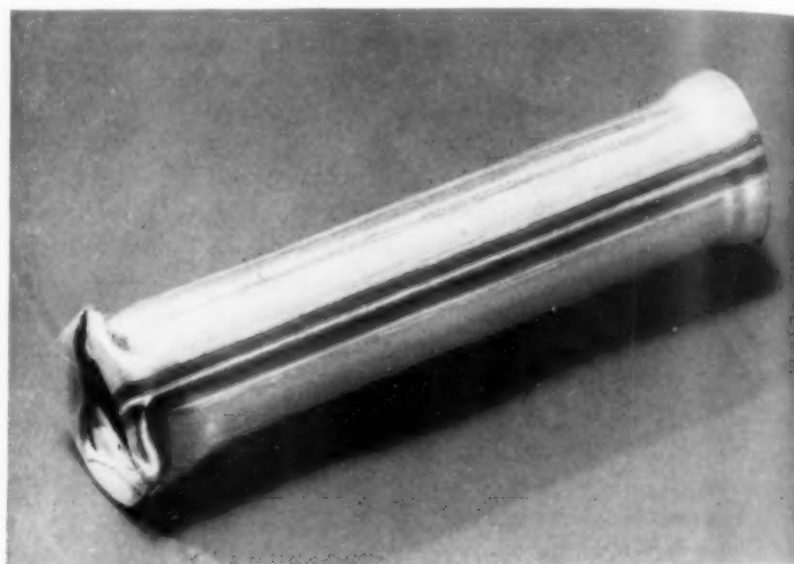
Standardized Hardenability Test

COLUMBUS, Ohio

To the Readers of METAL PROGRESS:

Undoubtedly many have already noted the error which exists in the diagram of the fixture for end-quench hardenability testing on page 910 of the December issue. The height of the unimpeded water jet is indicated to be $2\frac{1}{2}$ in. from the water quenched end of the specimen; actually it should be $2\frac{1}{2}$ in. above the orifice.

I wonder if the Steel Standardization Group



Piece of Tube, as Welded, Expanded at One End and Collapsed at Other to Test the Joint. Slight outside welt is usually trimmed by a cutting tool set beyond the welding head; inside welt is very small

would find it more accurate to duplicate the water pressure passing through the orifice by measuring the diameter of the fan-shaped deflection of the water from the bottom of a dummy specimen set in the fixture, rather than trying to estimate the height of a bobbing unimpeded stream.

JOHN G. KURA
Metallurgical Research Engineer
Battelle Memorial Institute

Reply by Mr. Jominy

The idea of measuring the diameter of the fan shaped deflection of water appeals to me, particularly because it can be done while the specimen is being cooled, so that any change in water pressure during the quench could be adjusted by changing the valve setting. The water pressure has not been a matter of con-

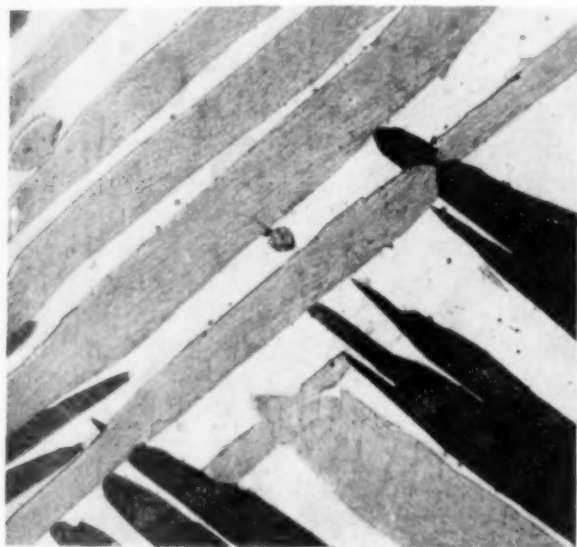
cern in making the hardenability test since rather wide variation in pressure gives practically identical results. It is for this reason that the height of 2½ in. has been sufficiently accurate in specifying water pressure. W. E. J.

Interlocking Twins

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

The other day one of the metallographers in our laboratory discovered the rather interesting and, to me, unique structure shown herewith. The brass analyzed 59.83% Cu, 0.17% Pb, 0.01% Fe, 0.68% Sn and 39.31% Zn (by difference).



The sample in question was furnace cooled from 1470° F. The photomicrograph was taken at 250 diameters, the specimen having been etched in 1 to 4 hydrogen peroxide-ammonium hydroxide.

An interlocking joint of the alpha plates is shown in the upper right hand corner.

HARRY P. CROFT

Asst. Director of Research
Chase Brass & Copper Co.

Are You Studying Corrosion?

PITTSBURGH, PA.

To the Readers of METAL PROGRESS:

The American Coordinating Committee on Corrosion is contemplating revising its confidential directory of technologists actively engaged in studies on corrosion and its prevention. The Committee comprises delegates from the 17 major technical societies, together with

representatives from the principal industrial research institutes and the National Bureau of Standards. Its directory currently lists some 400 investigators in a diversity of corrosion-preventive fields, selected on the basis of questionnaires circulated to the membership of the committee's member societies. While it is felt that the list is quite complete, there are undoubtedly some individuals who were not reached during the original circularization. Accordingly, the Committee now requests that all persons actively engaged in corrosion researches who have not been contacted write to the undersigned for further details and forms for directory listing.

GEORGE H. YOUNG

Mellon Institute of Industrial Research

Grain Size Vs. Notched-Bar Test

COVENTRY, ENGLAND

To the Readers of METAL PROGRESS:

I was somewhat interested in the apparently contradictory statements contained in "Comments by the Editor" in the September 1941 issue of METAL PROGRESS, and "Relation Between Grain Size and Toughness of Steel" in *Heat Treating and Forging* for July 1941.

In your article you suggest that it is up to the consumer to specify steel by its properties rather than by its composition, and I heartily endorse this remark. However, you suggest that toughness is to be indicated by its grain size, and from your remarks in the preceding paragraph relating to the use of aluminum by steel manufacturers, you imply "grain size as denoted by the McQuaid-Ehn or related tests".

The abstract referred to in *Heat Treating and Forging*, reporting the conclusions reached by SAMUEL J. ROSENBERG and DANIEL H. GAGON as a result of experiments made at the National Bureau of Standards, suggests that there is no relation between grain size and toughness. Reading further into this brief article, it appears that their experiments were made on samples having grain size variations produced by the relative temperatures at which the steel was finished, presumably on one cast only, in which case the "inherent grain size" of all the samples tested would be similar.

In view of these apparently conflicting opinions it would therefore always seem advisable to differentiate between apparent grain size, and austenitic or inherent grain size as

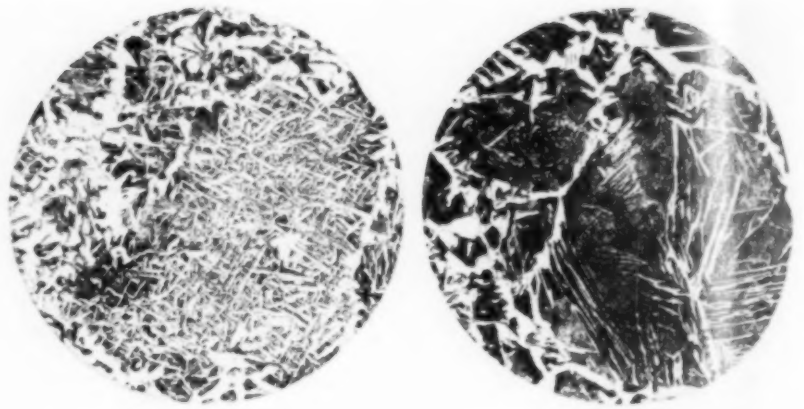
established by the usual methods given in A.S.T.M. specification E19 — 39T.

The attached micrographs are of interest, illustrating that certain steels in an exceptionally coarse-grained condition can possess excellent impact strength as measured by the Izod test. This sample is of the straight carbon-manganese variety analyzing 0.22% carbon and 1.40% manganese, having an ultimate strength of 87,360 psi. and an Izod value of 47 to 52 ft.-lb.; incidentally, this material was taken from an American automobile, and the writer expressed the opinion at the time it was examined several years ago that the coarse grain was intentional, as in this condition its elastic limit and damping capacity would be high. Unfortunately the inherent grain size of the steel was not determined at the time, and the sample has long since disappeared.

That inherent grain size is definitely related to toughness has been shown by a number of American workers, and in this country by SWINDEN and BOLSOVER ("Controlled Grain Size in Steel", *Journal of the Iron and Steel Institute*, 1936) and others. One of the most useful characteristics of grain size control, however, is its relationship to distortion in heat treatment, and this has been particularly observed by the writer in the case of nickel-chromium case-hardening gear steel similar to S.A.E. 3312, but with chromium limits of 0.9 to 1.2%. An extensive investigation of this steel was made several years ago on the relationship of distortion in heat treatment to (a) microstructure, (b) annealing or softening treatment after forging, (c) stress relieving treatment after rough machining and (d) inherent grain size. While all these proved to have a pronounced effect, the primary factor was inherent grain size, and this was confirmed over a lengthy period by examination of gears rejected as noisy; in every case these had a grain size rating less than 3, whereas quiet gears rated at more than 5. A grain size of 5 to 6 was accordingly specified, and since that time the number of gears rejected for noise resulting from distortion has been negligible.

R. J. BROWN

Chemist and Metallurgist
Morris Motors, Ltd.
Engines Branch



Carbon-Manganese Steel (at 125 Diameters) From American Automobile; Coarse Grained But Very Tough — Izod 50 Ft.-Lb.

Mr. Rosenberg's Comments

It is realized that practically all published work, both in this country and abroad, relating to the effect of grain size upon notched-bar impact resistance, shows a quite definite trend toward the conclusion that, for any particular type of steel, fine grain is conducive to increased toughness. The belief, however, that fine grain *per se* is a guarantee of superior toughness is not only unjustified, but in many cases even dangerous.

In discussing this subject, we should understand clearly what is meant by toughness and what is meant by grain size.

Toughness to many engineers connotes high notched-impact values obtained on specimens tested at room temperature. This is a false conception. A steel having a notched-impact value of 100 ft.-lb. is not twice as tough as a steel of 50 ft.-lb. To secure an estimate of the relative toughness of two steels, it is necessary to study the effect of some variable such as change in size of test specimen, or change in test temperature. If notched-bar tests are made over a range of sub-atmospheric temperatures, the lower the test temperature at which the impact value drops more or less markedly and at which the fracture changes from fibrous to granular, the tougher is that steel, regardless of whether its impact value at room temperature is higher or lower than that of a second steel.

To further complicate any discussion, many engineers, and even some metallurgists, have a confused idea of what is meant by grain size. It is definitely wrong to use the adjective "inherent" in describing grain size. This word implies that the grain size is permanently contained in the steel, therefore none other can

exist. At practically any steel, regardless of method of manufacture, can be made coarse or fine grained at will, depending entirely on variations in heat treatment. The McQuaid-Ehn grain size, frequently (and wrongly) referred to as the "inherent" grain size, shows merely the size of the austenitic grains developed after a somewhat prolonged exposure at a carburizing temperature of 1700° F. This useful test was developed originally as a means of checking on the casehardening qualities of carburizing steels, but it has been perverted to many unsuitable uses.

The important point is this: In heat treated steels, the effective grain size is that existing in the austenite *at the hardening temperature* (providing no overheating has occurred). In normalized steels the effective grain size is that existing at the normalizing temperature. Very frequently the McQuaid-Ehn grain size (at carburizing temperatures) bears no relation to the austenitic grain size developed at the lower heat treating (normal quenching) temperatures.

Mr. BROWN refers to an abstract of a paper by DANIEL H. GAGON and the writer. This abstract was not a very accurate description of the contents of the paper, which is entitled "Effects of Grain Size and Heat Treatment Upon Impact Toughness at Low Temperatures of Medium Carbon Forging Steel", and which was published as Research Paper No. 1410 of the National Bureau of Standards, and as Preprint No. 12 for the 1941 Convention. In our studies tests were made, not on samples from one heat of steel finished at different temperatures, but on six separate heats of S.A.E. 1050 steel, all of which were subjected to similar hot rolling operations. The deoxidation practice was varied, however, so as to produce coarse McQuaid-Ehn grain sizes in some of the heats, and fine McQuaid-Ehn grain sizes in other of the heats. Although these steels had markedly different McQuaid-Ehn grain sizes, the austenitic grain sizes of all six steels at the hardening temperature used (1475° F.) were quite fine.

Impact tests were made on the steels as quenched from 1475° F. and tempered at different temperatures. Judging the relative toughness of the steels by the temperature range during which the

impact values decreased most rapidly — a criterion mentioned at the outset — it was found that fine McQuaid-Ehn grain size was no assurance of superior impact toughness, nor was coarse McQuaid-Ehn grain size any indication of inferior impact toughness. Nor was the austenitic grain size at the hardening temperature any guide to the impact toughness of these steels.

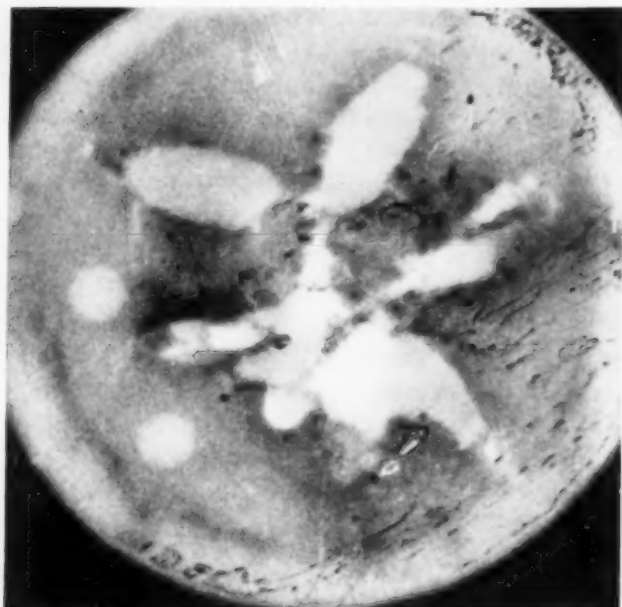
Under any one condition of heat treatment, certain of these steels were tougher than others and this superiority was maintained under other conditions of heat treatment. The results of the tests indicated that S.A.E. 1050 steel, in various conditions of heat treatment, does not have a characteristic resistance to impact in the same sense, for instance, as it has a characteristic tensile strength. Each individual heat, when heat treated, apparently has a certain resistance to impact between certain limits, and this is dependent upon one or more factors not at present recognized.

S. J. R.



Tin Can Camera. In a dark room the steel disk is clamped between two sheets of photographic film and two small brass plates. The tin can was used to protect the device from all light during many hours of necessary exposure. The film recorded the rays from radio-active atoms of phosphorus in the steel disk

Photograph of the Inside of a Blowy Cast Steel Disk, Somewhat Larger Than the One Shown in the Other View. The light areas on the picture show the concentration of phosphorus around blow-holes as recorded on the film by the invisible rays from tracer atoms



Phosphorus Located by Radio-Active Tracers

EAST PITTSBURGH, PA.

To the Readers of METAL PROGRESS:

Radio-active substances have been used for a considerable time in medical research to trace movements of fluids through the life processes of organisms. They are also of use to metallurgical science. For instance, radio-active silver has been electroplated on normal silver, and the subsequent diffusion ("self-diffusion", it is called) has been accurately measured at various times and temperatures, thus establishing the mathematical relationships for this fundamental phenomenon.

Similarly phosphorus, sulphur, carbon, manganese and silicon can be made into radio-active "tracers" by exposing them to a stream of high speed electrical particles thrown out by an "atom-smasher". In a representative experiment, some phosphorus was so treated, added to a small melt of rather gassy steel in a high frequency induction furnace, and cast into a 2-in. disk. Phosphorus made temporarily radio-active is no different chemically from normal phosphorus; in the iron alloy, therefore, the two are interchangeable.

To locate the phosphorus *within* the steel

disk (not alone on its surface, which could obviously be done by proper etching) a simple "camera", consisting of a tin can, two small brass disks, two films and a screw clamp, was improvised. Assembled as shown in the accompanying view, it will record on the photographic film the rays from any artificially radio-active tracers. The tin can merely is a light-tight box in which to store the assembly for the necessary time. The developed film revealed blotches caused by the rays from the phosphorus tracers. The light areas on the print corresponded with cavities or blow-holes in the steel disk, indicating the phosphorus had concentrated at or near the surfaces of these holes.

W. M. SHOUPP
Research Laboratories
Westinghouse Electric & Mfg. Co.

Lucite Specimen Holder

EUCLID, OHIO

To the Readers of METAL PROGRESS:

Perhaps some metallographers are having difficulty getting glass specimen holders for metalloscopes.

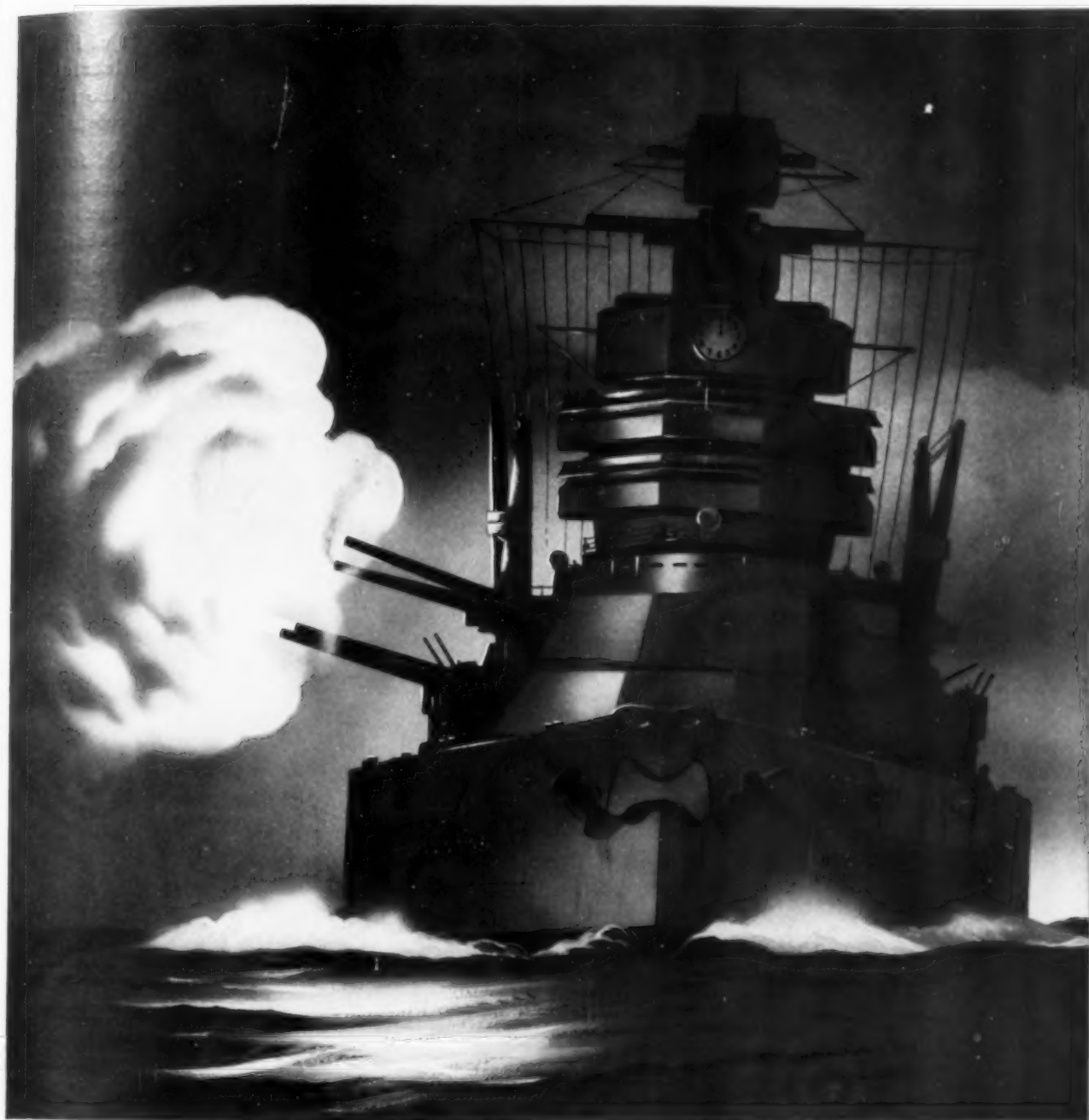
Here is a specimen holder that is light, transparent and strong. You're right, it's lucite! It can be readily cut or turned to suit the particular need. The specimen holder shown is for mounts one inch in diameter, and has an



undercut shelf to accommodate high power objectives. It was made in the laboratory in a few minutes and has proved superior to brass, steel, or any other material for this purpose.

We hope that there will be enough lucite on hand!

VERNE PULSIFER
Research Assistant
Chase Brass & Copper Co.



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Personals

J. Eugene Jackson ☉, metallurgical engineer with the Copper Iron and Steel Development Association, Cleveland, has accepted a position as senior industrial analyst in the Copper and Brass Division, Inventory and Requisition Section, Division of Industrial Operations, W.P.B.

Major A. W. Sikes ☉, chemical warfare officer on duty at Corps Area Headquarters in Chicago, has been ordered to report to the Army Command and General Staff School at Fort Leavenworth, Kansas, for a two months' course of instruction.

William Mikulas ☉ has been made metallurgist for the Propeller Division of Nash-Kelvinator Corp., Lansing, Mich.

George M. Enos ☉ of the Cincinnati Ordnance District has been promoted from the rank of major to lieutenant colonel.

James F. Ednie ☉, formerly associated with the metallurgical and research department of the Federated Metals Division of American Smelting and Refining Co., has been made chief metallurgist of the technical and metallurgical department of the Duquesne Smelting Corp., Pittsburgh.

Sydney Nashner ☉, formerly metallurgist, Inland Steel Co., Indiana Harbor, Ind., is now first lieutenant, Production Division, Pine Bluff Arsenal, Pine Bluff, Ark.

A. P. Bellinghausen ☉ has been appointed chief inspector of the Quad Cities Sub-Office, Chicago Ordnance District, Davenport, Iowa.

Lieut. George B. Munroe ☉ of the Army Air Corps, 1940 graduate of Missouri School of Mines and Metallurgy, is reported safe in Australia after a bomber crash in the jungle.

Joseph V. Kielb ☉ is welding supervisor at Harrison Radiator Division, General Motors Corp., Lockport, N. Y.

Walter S. Gips ☉ has been made metallurgical engineer and consultant for the operating staff of the N. Rhodiman Oxygen and Acetylene Co., N'Dola, N. Rhodesia, Africa.

Gordon McMillin ☉, formerly metallurgist for the Standard Brake Shoe & Foundry Co., Pine Bluff, Ark., and Memphis, Tenn., is now metallurgist for the General Steel Castings Corp., Eddystone, Pa., Madison and Granite City, Ill.

Promoted by The Linde Air Products Co.: **J. A. Rea** ☉, from service engineer, Cleveland district sales office, to supervisor, process service, Indianapolis district sales office.

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MILWAUKEE, WISCONSIN

Personals

George W. Whitney ☼ is now chief metallurgist of Emsco Derrick and Equipment Co. of Los Angeles.

K. W. Ostrom ☼ is now stationed in Washington, D. C., working in the General Industrial Division of the War Production Board.

J. R. Fritze ☼ of the Edison General Electric Appliance Co., Chicago, is now connected with the Bureau of Conservation of Materials in Washington, D. C.

Cyril Grindrod ☼ has resigned as sales engineer of Wyck-off Drawn Steel Co., Chicago, to accept the position of assistant vice-president in charge of production of the S. F. Bowser Co., Ft. Wayne, Ind.

H. A. Moorhead ☼ has been appointed metallurgical engineer, bar and semi-finished products, Carnegie-Illinois Steel Corp., Chicago.

John W. Sands ☼, formerly metallurgist International Nickel Co., New York, is now consultant for the Bureau of Industrial Conservation, War Production Board, Washington.

Theodore J. Sokol ☼ has been made assistant to vice-president, National City Bank, Cleveland, with duties of an engineering nature.

Transferred: Harold C. Thomas ☼, from the metallurgical section, material laboratory, New York Navy Yard, to the Mare Island Navy Yard at Vallejo, Calif.

Promoted: G. P. Burks ☼ from chief chemist, Gary Works, Carnegie-Illinois Steel Corp., to second assistant superintendent of blast furnaces.

John A. Shaw ☼ has accepted a position as research and development engineer with Fort Pitt Steel Casting Co. at McKeesport, Pa.

A. A. Straub ☼ has been made furnace engineer and priorities director in Washington, D. C., for United Engineering and Foundry Co. of Pittsburgh.

John L. Burns ☼ is now with Booz-Fry-Allen & Hamilton of Chicago, management counsellors and business surveys.

Trem Watson ☼, formerly with Timbrol Limited at Rhodes, N.S.W. doing instrumentation work, has joined the Clyde Engineering Co. in Australia as chief metallurgist.

L. D. Orr ☼ has resigned as metallurgical engineer in the development organization of Western Electric Co., Chicago, to become metallurgist for Nash-Kelvinator Corp., Propeller Division, Lansing, Mich.



From Coast . . . To Coast

The Talk of the Machine Shops Wherever
Boker's Tool Steels are used - - - - - *"They Satisfy!"*

NOVO

{ 18-4-1 Type High Speed Steel.

TWIN MO

{ 6-6-2 Tungsten Molybdenum High Speed Steel.

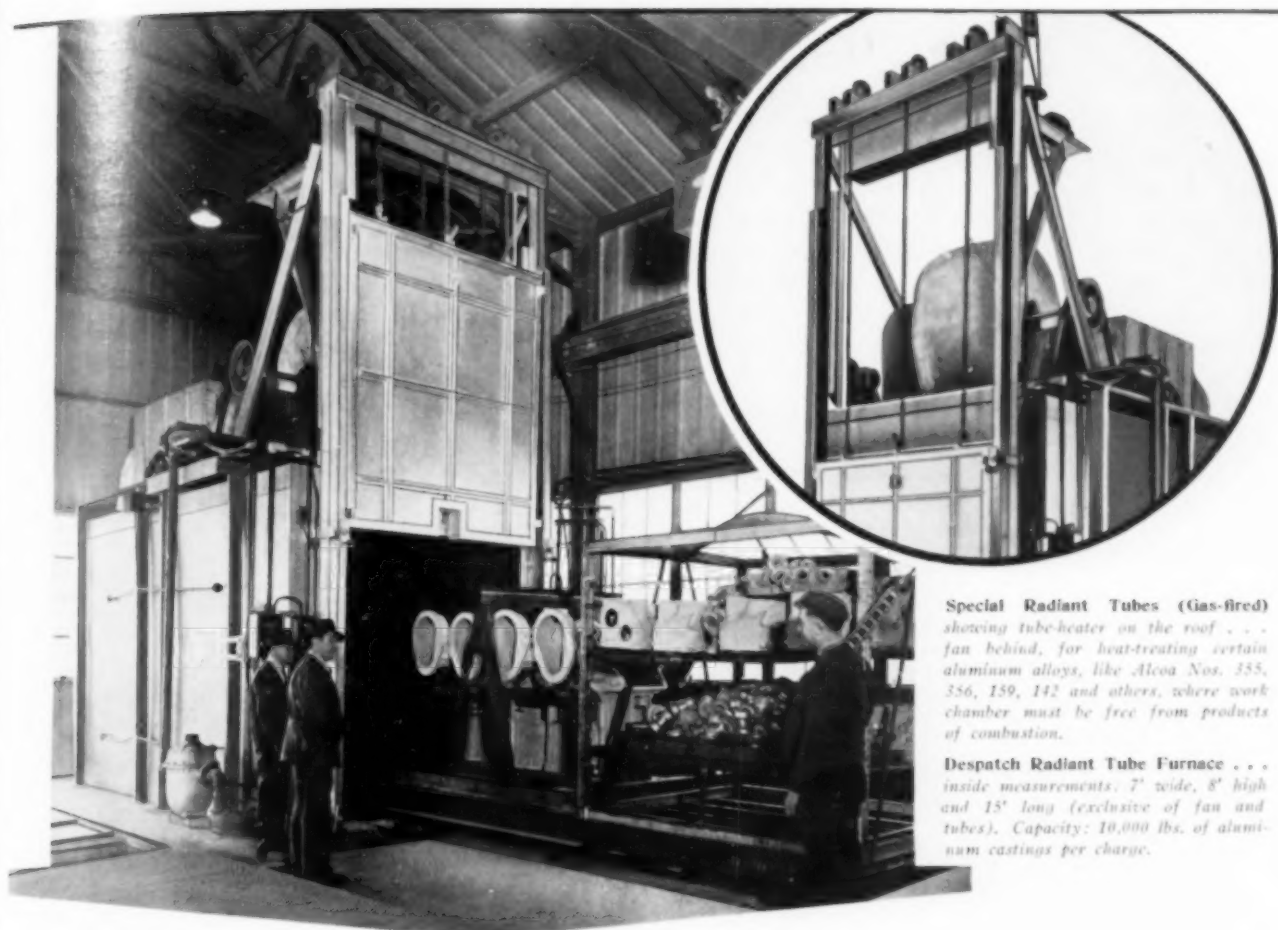
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have served the industry
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Special Radiant Tubes (Gas-fired) showing tube-heater on the roof . . . fan behind, for heat-treating certain aluminum alloys, like Alcoa Nos. 355, 356, 159, 142 and others, where work chamber must be free from products of combustion.

Despatch Radiant Tube Furnace . . . inside measurements: 7' wide, 8' high and 15' long (exclusive of fan and tubes). Capacity: 10,000 lbs. of aluminum castings per charge.

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With a man-sized job to be done, to increase aluminum casting output, we can think of no better place to go than to Mr. J. L. Schmeller, executive president of The National Bronze and Aluminum Foundry Company, Cleveland, Ohio. His long experience in non-ferrous foundry work, together with his energy and resourcefulness, have made Mr. Schmeller a national figure in this race for more wartime production.

When Mr. Schmeller needs more heat-treating capacity, he looks in turn to Despatch. He has records to show that the Despatch radiant tube furnace will produce more

castings per month and still cut production costs. There are several Despatch direct-fired and radiant tube furnaces at NBACO.

Many other metallurgical industries have found Despatch furnaces exceptionally successful for such processes as aging, annealing, bluing, normalizing, solution heat-treating, precipitation heat-treating, tempering and drawing, and stress-relieving. Results invariably show the definite superiority of the Despatch furnace design. It gives greater production, highest quality results with marked operating economies.

WRITE TODAY

FOR BULLETIN No. 81-F for full information about Despatch furnaces for heat-treating all types of aluminum and magnesium alloys.



DESPATCH

OVEN COMPANY MINNEAPOLIS, MINNESOTA

British Rails

(Continued from page 675)

type of welding having been used.

The issue in 1904 of the first British specification for rails resulted in the substitution of a few standard sections for an indefinite number previously used on the different railways. The bull-head type of rail, sup-

ported in cast iron chairs and held to gage by wooden or coiled steel keys, is in universal use, and the weight per yard, which has seen little change in the last 30 years, is 95 lb. and 100 lb., a limited tonnage of 85-lb. rails being used in secondary tracks. The 100-lb. rail is 5.91 in. deep; the web and foot are identical in both sections being $\frac{3}{4}$ in. and $2\frac{3}{4}$ in. wide.

The reason why heavier rail

sections are not considered necessary is partly that maximum locomotive axle loads in Great Britain are not allowed to exceed 50,400 lb., and also that the use of three-cylinder and four-cylinder propulsion in all the larger British locomotive types so improves the balancing and reduces hammer-blow that rails of this weight have ample girder strength to stand up to their work with supporting chairs spaced at 2 ft. 6 in. Given adequate strength and life, the economy in first cost of laying new rail which does not exceed 100 lb. per yd. in weight needs no stress.

The London Midland & Scottish and London & North Eastern Railways have, during the past five years, experimented with flat-bottom rail of both the British Standard 110-lb. and the American Railway Engineering Association's 130-lb. section. The purpose of these tests in important main lines is to compare initial and maintenance costs, whereby it may be possible to decide whether a future change from bull-head to flat-bottom track would be justified.

In conclusion, attention is drawn to the last figure, which summarizes the changes that have taken place in the chemical composition, hardness and microstructure of British rails during the past half-century. The 1890 rail illustrated is one of a series of old rails of lengthy service which, as previously mentioned, were recently examined by modern metallographic methods, while the 1940 sorbitized rail was a routine sample of new rail tested in the same manner. Apart from the noticeable difference in the profiles of the two sections—influenced to some degree in the early section by wear and corrosion—the most valuable development has been the capacity of the new rail to work harden in service to a greater hardness than was possible with the old rail.

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MORE TANKS—TO SEND THE YANKS!**



Here at Pangborn the boys are fighting mad. They don't want to remember Pearl Harbor. They want to avenge Pearl Harbor. So day and night they're on the job—working grimly for their part in the taking of Tokio, the bombing of Berlin, the razing of Rome. Deep down, where it really matters, the war has reached home.

That's why—to the last—we're in this thing with hot perspiring brows and clenching fists. Our men have something tremendous to work for—and they know it. They express their willingness to help, not in singing the Yanks are coming—but in getting out—every day and night—bigger and better ROTO-BLAST and Air Blast Barrels, Tables, Cabinets and Rooms to blast clean more shells, more ships, more planes, more tanks—TO SEND THE YANKS!

**MORE OF EVERYTHING TO SEND THE YANKS. IT CAN BE DONE! LET
PANGBORN HELP YOU DO IT!**

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WORLD'S LARGEST MANUFACTURER OF DUST COLLECTING AND BLAST CLEANING EQUIPMENT
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OF METALS**

INCREASE FURNACE OUTPUT

Quality and Quantity are most essential in producing tools of war.

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Whether you heat-treat steel — make die castings — bake enamel or do galvanizing — your war materiel, furnaces, time and money are backed on accurate temperature control.

That is why leading companies are turning to Brown and Minneapolis-Honeywell Control Systems for positive control of temperature processes. They are applicable for any type furnace — oil, gas or electric. You'll find them everywhere, on all makes of furnaces used for every kind of work where precision temperature measurement and control mean low cost furnace operation.

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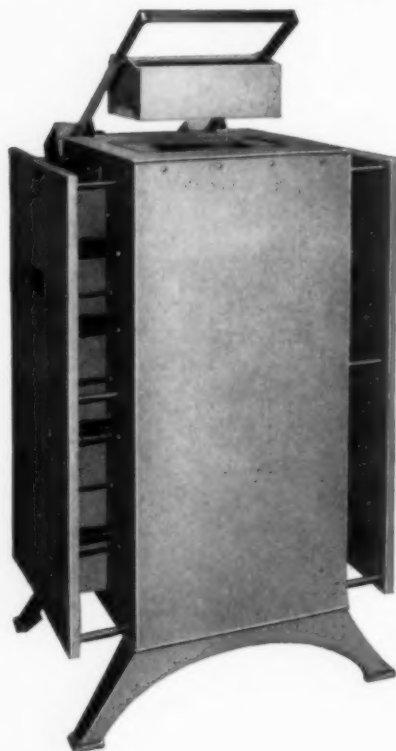
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TO MEASURE AND TO CONTROL IS TO ECONOMIZE

Vertical Hardening with *Packaged Atmosphere*



Long tools of high speed steel that should be treated in a vertical position can now have the advantages of *Sentry Packaged Atmosphere*. Vertical Hardening eliminates tendency of the tools to warp or change shape when hot. *Sentry Diamond Blocks* — *The Packaged Atmosphere Method* — automatically maintain a neutral atmosphere resulting in maximum hardness — no scale — no reduction in size — no decarburization — consistent maximum quantity.

Write for Bulletin 1023A describing two sizes of *Sentry Vertical Furnaces*.



Sentry Diamond Blocks automatically maintain a neutral atmosphere that does not depend on analysis or manipulation. Available in sizes to meet requirements.

The Sentry Company
FOXBORO, MASS., U. S. A.

Saving Manganese

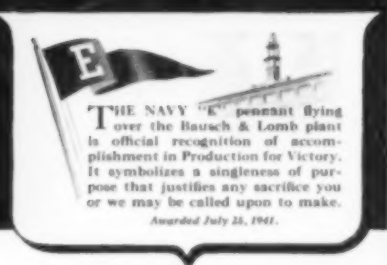
(Cont. from page 650) properties. For example, if a steel containing 0.035% sulphur is at present rolled satisfactorily with 0.60% manganese, it is entirely conceivable that if the steel should contain 0.025% sulphur the manganese could be considerably decreased and still retain a satisfactory surface. If in preliminary tests, on the other hand, a steel of the above grade happened to indicate that it would be tapped to give 0.050% sulphur, it is conceivable that the best production would be obtained if the manganese is raised higher than the 0.60% commonly aimed at. With these changes in manganese to give good rolling properties the carbon or silicon contents of the steel, or both, might be varied inversely with the manganese to secure a given range of physical properties. Such a practice would have two advantages, (a) it would give the best production for a given grade of steel from the standpoint of conditioning costs, and (b) it would permit a considerable decrease in manganese if the average sulphur content of the raw materials could be decreased. In other words, lime to flux off the sulphur would be substituted for manganese to neutralize its presence. This is entirely feasible if the situation were sufficiently acute that it became more necessary to conserve manganese than to conserve lime and furnace time.

Summary

In summary, the Committee believes that if the supply situation becomes critical, the plan outlined below should be followed:

1. As a first step, the manganese content of steels falling in Class A could be reduced. This class includes high manganese sheet steel, some of the commercial high manganese steel rails, bars, much of the sheet and strip steel plates, and other products. It is expected that 10% of the total ferromanganese can be saved by this procedure.
2. As a second step, to be taken only if the need is great enough to warrant an adverse effect on production and quality, the manganese content in the Class B steels could be reduced. This class includes tinplate, some grades of tubing, rods, wire, sheet and strip. It is expected that another saving of 10% of the total ferromanganese can be so made by this procedure.
3. Any action to reduce the manganese content in steel products should be taken only after careful thought by producer and consumer.

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Dr. Braddock's Microscope Was Commissioned Today

DR. BRADDOCK wants a new microscope—a Bausch & Lomb Microscope . . . and he's going to get it. It won't be today, though, for today America commissioned a new cruiser.

On this ship there are many optical instruments with a myriad of optical parts, made by the same hands that, in other times, might be grinding the lenses for Dr. Braddock's microscope. There are range finders fore and aft, and a score of smaller ones in strategic places about the ship. The glasses with which the officers scan the horizon are Bausch & Lomb products. Yes, and there's a

B&L Microscope, a duplicate of the one Dr. Braddock wants, in the laboratory of the ship's hospital.

Dr. Braddock still wants his microscope, but because he knows these things he is willing to wait. Thousands of "Dr. Braddocks" are making earlier victory possible.

Throughout the Bausch & Lomb plant, optical engineers and optical craftsmen are working long and tirelessly to further America's war effort. The lessons they are learning in the white heat of the drive for Victory will be available later to further the peacetime interests of science and industry.



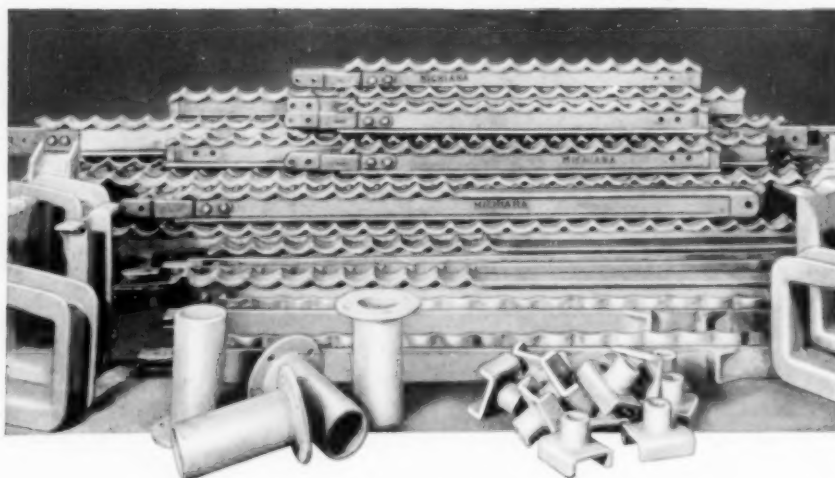
BAUSCH & LOMB
OPTICAL CO. • ROCHESTER, NEW YORK
ESTABLISHED 1853

Welding of Tank Armor*

TANKS or "naval landships", 49 in number, first went into action at Flers on Sept. 15, 1916, during the first World War. As the parts of these machines were made in various parts of the country, exact machining of the plates was essential. The resulting close fit proved of great value

in counteracting "splash" from lead bullets. In later models splash plates were fitted to minimize the danger, which was very real unless the gaps between the plates were of the order of 0.002 in. or less, because of the penetration by lead, liquefied on impact. The armor plate was a

MICHIANA Heat-Resistant Alloy
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UNIFORM QUALITY AND ACCURACY MEAN STEADY TOP PRODUCTION

Particularly where many heat-resistant alloy castings are parts of complete assemblies, are uniformity of quality and accuracy of each part important to insure maximum performance.

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ALLOY CASTINGS

- Muffles • Retorts • Sprockets • Chains
- Boxes • Pots • Heat-Resistant and
- Rails • Grids Stainless Steel Cast-
- Rolls • Tubes ings of all kinds.

nickel-chromium-vanadium steel.

For the next 17 or 18 years the development of tanks and vehicles proceeded slowly, except in the Axis countries and the U.S.S.R. Up to 1936 riveted construction was utilized in England, a method that involved the drilling of difficult alloy steel, its hardening without distortion, its fitting to an accurately drilled frame, and the frequent use of spacers to fill any gap wider than 0.002 in. But if such fully machined plates are not used, there are three alternatives:

1. Cast plates, and castings for gun turrets and side armor. Although very large steel castings can be made in quantity, it is necessary to heat treat to remove casting stresses. After machining, the castings must be hardened and tempered to requisite bullet resistance. Great care will be required to prevent distortion. Cast assemblies in general will be bolted or riveted together and are usually about 25% thicker than rolled plate.

2. A fabricated structure made up of welded plates and castings, if the latter are necessary. This method has much to commend it; if care is given to the preliminary details, rapid assembly can be attained.

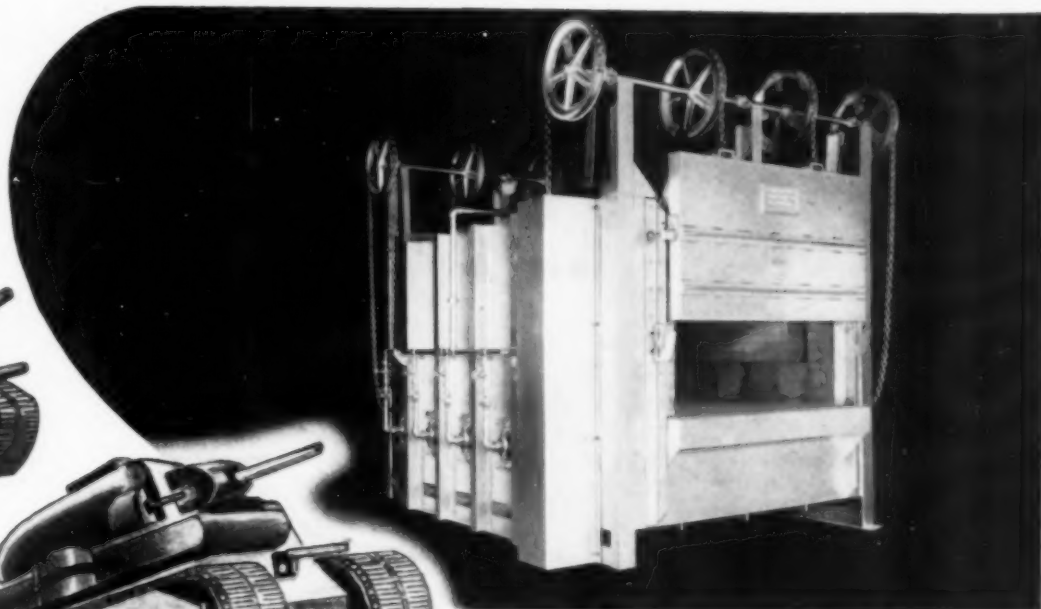
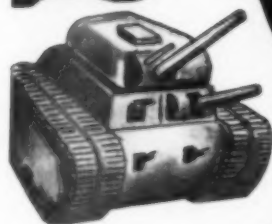
3. The welding together of castings whose abutting edges are "battered" with a welded-on layer of self-hardening steel, so as to prevent the weld metal from causing trouble in the plate alongside the joints.

Gas cutting and welding of bullet-proof plate is comparatively new, but the writer has been carrying out both for nearly five years. Should the steel be air hardening, the cut edges may be flame softened, if speed of cutting cannot be modified so as to obviate its necessity. This

(Continued on page 706)

*Abstract from "The Production of Armored Fighting Vehicles", by W. E. Woodward, Lecturer in Metallurgy, Cambridge University (*The Engineer*, March 20, 1942, page 251.)

STANDARD IS SETTING NEW STANDARDS



*... in the battle for more
heat treating production ...*

Because all production operations are controlled in one coordinated plant . . . because of the special applications of burner equipment . . . because of the outstanding qualities of the Zero refractory cements used . . . and because of 28 years of successful experience in licking hundreds of heat treating problems — S.F.E. furnaces are setting new standards of heat treating production in this war of metals — and setting speedy delivery dates.

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FUEL ENGINEERING COMPANY

667 S. Post Ave., Detroit, Michigan

VI. 1 - 5500

Welded Armor

(Continued from page 700)

applies to nickel-chromium-molybdenum steels, which are so largely employed as "homogeneous-hard" plate. Weldments need no accurate machining of plates; in fact, butts are perfectly satisfactory if cut to size by gas flame cutting devices.

In this connection the following points require attention:

1. For flame cutting of plates modern machines are to be used, giving an accuracy of at least $\frac{1}{16}$ in. to line.
2. During welding, large plates should be flexibly held to permit expansion, contraction, and "breathing".
3. Maintain the correct minimum welding gap, to insure maximum bullet resistance and

avoid undue welding contraction.

4. Plates assembled in the jig should be preheated.

5. Avoid an unduly rapid cooling of the weld.

6. Some form of manipulator jig is essential to bring the joints into a more-or-less horizontal position for welding.

7. Where a hard outer weld is applied to supplement the softer austenitic weld, care should be taken that the hard run of weld does not wash over onto the armor plate.

8. Correct sequence of welding operations is of the utmost importance, and is only found by actual experiment.

The welded structure is much more immune to attack, as there are no open joints through which lead "splash" can occur, or the contents of gasoline bombs seep. As rivets are not employed, there is no chance of their being shot through to become a second projectile inside the hull. A plate in the structure damaged by attack can be speedily repaired in the field by cutting out the damaged portion and welding on a patch plate.

Early in 1936 Germany possessed quantities of welded tanks; at Hitler's birthday parade in that year at least 50 such vehicles were drawn up in Unter den Linden. Photographs show welding very prominently.

In the Battle of Libya it has been apparently impossible to repair our damaged vehicles by riveting quickly enough to maintain our position, whereas stress has been repeatedly laid upon the fact that the German general, Rommel, is able to get his damaged vehicles back into commission with exceptional speed. Mr. Churchill has said, "It may well be that the enemy repairs his damaged vehicles much more quickly." No doubt these results are obtained from flame cutting and welding by bringing the apparatus to the damaged vehicle and not taking the vehicle back to a workshop.

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HIGH ALLOY
CASTINGS ... backed by 20
Years' Experience
with Chrome-Iron,
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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY



This "Spiralink-Jr." cast X-ite furnace belt-earthen weighs 10 1/4 lbs. per sq. ft. and has been running three years. ENGINEERED to MIN. Wt. & Max. SERVICE, this and hundreds of General Alloys Engineered Alloy applications have already reduced alloy weight to a minimum with proven reliability, increased life. IF YOU WANT TO HELP SAVE NICKEL & CHROME, VITAL VICTORY INGREDIENTS, call in a G. A. Engineer.

compensates you for two or three days of the well known Washington-run-around. Among the Classics, Polybius' "The Cycles of History" written about 150 B.C., selling the idea of Roman domination of the world, kind of takes the edge off of Adolph Nazisob. William Blake's "The Mental Traveler" should help compensate for the Gasoline ration in the East. If the forms from Washington seem difficult, get out your Kant's "Critique of Pure Reason", read three chapters and then tackle the form blindfolded. "The London Fire" from Samuel Pepys' Diary is now timely. For real relaxation we suggest Maugham's "Ashenden, or the British Agent", based on W. S. Maugham's experience as a British Spy in the "War to make the World Safe for Democracy." The later crop of spies seem to have been lame, halt, and blind, and were probably on a 40-hr. week.

IT doesn't take a detective to find the way to REALLY SAVE NICKEL FOR VICTORY, if he is REALLY LOOKING FOR IT. General Alloys "SPIRALINK" cast-link hearths weigh from 10 lbs. to 15 lbs. per square foot and are longer lived and far more economical than other types of belts in service, besides SAVING UP TO 50% IN ALLOY WEIGHT. G. A. Hinged-Trays give far longer life per pound of alloy than solid trays. G. A. "Twin-Link" and "I-O-Link" chains are designed for continuous service at high temperature, NOT copied, from malleable

chain design, that's why they weigh less, live longer. GENERAL ALLOYS COULD EASILY DOUBLE THE TONNAGE WE ARE NOW PRODUCING, MERELY BY SUBSTITUTING THE SCORES OF DUMB, HEAVY CASTINGS AVAILABLE FOR THE THIN WALL CONTAINERS AND LIGHT WEIGHT CASTINGS WE ARE PRODUCING. Who would make this difficult, tricky, and super-accurate work, if we didn't? Try naming those you think could do it. Users are thankful that the high speed fans in modern furnaces, and similar SERVICE BOTTLE-NECK alloy parts are DEPENDABLE & LONG LIVED, — the great bulk of them are G. A. Cast.

NEARLY everyone has read Adolph Hitler's "Mein Kampf", which tells pointedly what is biting the world. Karl Marx's "Capital" was the bible of many who are biting and blighting our war effort and "Our Way of Life", but Marx is now regarded as a conservative by many sponsoring Labor Rule and Redistribution of Wealth. Even our Russian pals didn't shoot many Engineers and Metallurgists, but they wouldn't think of paying them \$1.75 per hour with 70 hrs. per week, which is foremen's pay in local shipyards. Karl would spin in his grave on that one. The Book of Job is a fair catalyst for "Das Kapital", or,—how about reading some "ads" in METAL PROGRESS?

—H. H. Harris.

So, those sons of Nippons are smelling the cordite fragrance of the best zephyr of the U. S. Airforce in the Pacific. The "Zephyr" will be a gale. In the teeth of the gale will be the Japsobs' pants. Right off the "Graves" outside Boston Harbor, a new U. S. Warship was having her sea trials; about a mile away was a U. S. Destroyer. Up came a Sub. conning-tower out of water, surfaced for about ten seconds, had a look-see, and submerged. We didn't get that one. Those Subs. have brought us a new cure for burns,—common sea water. Burned crewmen from burning tankers survive far worse burns through prolonged immersion in sea water than they could have lived through on shore.

In describing the ideal story, W. Somerset Maugham says of the plot, "It starts with a set of circumstances which have consequences but of which the causes can be ignored; and these consequences, in their turn the cause of other circumstances, are pursued till a point is reached when the reader is satisfied that they are the cause of no further consequences that need be considered." Substitute the word WAR for Plot. We must do unto those Nazisobs, and Japsobs and Wopsobs, and all the little Axisobs UNTIL THEY ARE THE CAUSE OF NO FURTHER CONSEQUENCES THAT NEED BE CONSIDERED. Incidentally, the new RESTRICTIONS ON NICKEL & CHROMIUM in heat-resistant alloys will HAVE MANY CONSEQUENCES THAT NEED BE CONSIDERED. Considered in the light of the Engineering and Metallurgical EXPERIENCE of General Alloys Company to PREVENT PREVENTABLE INTERRUPTIONS IN VICTORY PRODUCTION. Anybody who tells you that these ERSATZALLOYS won't give trouble is all of. ah,—er,—ersatz. G.A. can ease the sting.

NOTHING like a little fertilizer for a good crop of votes, or strawberries. We've been spading it in and setting out 500 strawberry plants, and 200 raspberry bushes, as well as watermelon and cantaloupe seedlings, spuds, et cetera. This year we beat the bugs to the rhubarb. We're planting radishes to decoy the bugs off the watermelons, and we hope it doesn't work arsey-fersey, like our friend who put the Noxzema on his lilacs and the Vigoro on his sunburn. "Don't be a Cry Bird," said the Mess Sarge to "Beefer" at Camp Devons. The Rookie said, "Whatzis Cry Bird, Sarge?" "Well, 'Beefer', cracks Sarge, "The Cry Bird" sits on the North Pole and sez 'c-c-c-ry,—st it's cold, and he can't do nuttin' about it eder."

A little gardening is a great antidote for the poisons that creep into you during those sessions with the Patriots of labor. Good reading helps, too. Voltaire's "CANDIDE" at a pace, the telling of which somehow

GENERAL ALLOYS

THE QUALITY NAMES IN ALLOY
FOR HEAT CORROSION ABRASION

X-ite

Notes About Contributors

Scotch ancestry is almost implicit in the name of **Robert Cunningham Stewart**, and indeed the author of METAL PROGRESS's latest metallurgical mystery story was born in Scotland on Jan. 9, 1906. However, he migrated to Canada and was educated in Vancouver, B. C. and Hamilton, Ont. For 15 years he was in charge of the combined laboratories of John Bertram & Sons Co., Ltd. and Pratt & Whitney of Canada, Ltd. at Dundas, Ont. At present he is retained by Apco Petroleum Products Ltd. of Leaside, Ont., as a consulting metallurgist, and devotes full time to the problems that beset the war industries.

Charles H. Herty, Jr. is so active a member of technical societies and so prolific a publisher of investigations on physical chemistry of steel making that his career should be well known to most METAL PROGRESS readers (see September 1938 issue, page 270). His D.Sc. thesis (M.I.T. 1924) was on the interaction between gas, slag and metal in the openhearth, and that interest was continued in his work for the Bureau of Mines between 1926 and 1934. Since then he has been a research engineer with Bethlehem Steel Co., and is still known to the fraternity as "CHARLEY".

ROLAND P. KOEHRING



ROBERT C. STEWART



Roland P. Koehring has been identified with developments in powder metallurgy, particularly in the field of bearing metals, since 1925. Educated at Earlham College in Richmond, Ind., he accepted a position as chemist in the openhearth control laboratory of the American Rolling Mill Co. in 1919. A year later, when the General Motors Research Laboratories were being organized in Dayton, he joined the chemical and metallurgical research section as an assistant. When the laboratories were moved to Detroit in 1925 he remained behind, becoming metallurgist for the Moraine Products Division, the position he now holds. He served as chairman of the Dayton Chapter in 1934.

The metallurgist who writes like a technical reporter, **H. J. Sweeney**, and brings us the account of the steel maker's problems (page 676) studied chemistry at Cincinnati and metallurgy at Pittsburgh. After a novitiate as chemist for Wheeling Steel Corp., he went to Homestead Works of Carnegie-Illinois, first as combustion engineer and then as assistant openhearth superintendent. At present he is chief metallurgist in Republic's Youngstown district.

Of the two authors of the article on "Soft Steel for Plastic Molds" in last month's METAL PROGRESS, **Horace C. Disston** is the grandson of the founder of Henry Disston & Sons, Inc., Philadelphia. His present position is manager of steel sales. Mr. Disston graduated from Princeton University in 1928, and has spent much time in studying the developing steel problems of the plastic industry.

Co-author **John K. Desmond** is sales metallurgist for Henry Disston and Sons. Mr. Desmond was educated at Harvard University and has worked in the steel industry in a sales or metallurgical capacity since the last war when he served actively as a lieutenant in the Tank Corps. He is the author of several papers and originated a cone method for the determination of hardenability.

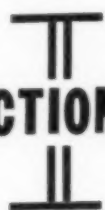
JOHN K. DESMOND



H. J. SWEENEY



ALLOY CONSTRUCTIONAL STEELS



by H. J. French, In Charge of Alloy Steel and Iron Development, International Nickel Co.

MR. FRENCH'S lectures on "Alloy Constructional Steels" were so well received at the 1941 Western Metal Congress that they have been made into a book.

This 275-page book covers alloys in commercial steels—why alloy steels are used—selection of alloy steels—typical commercial uses—commercial steels and manufacturing variables—high alloy steels—wear—how alloying elements may affect corrosion of steels—processing and special treatments.

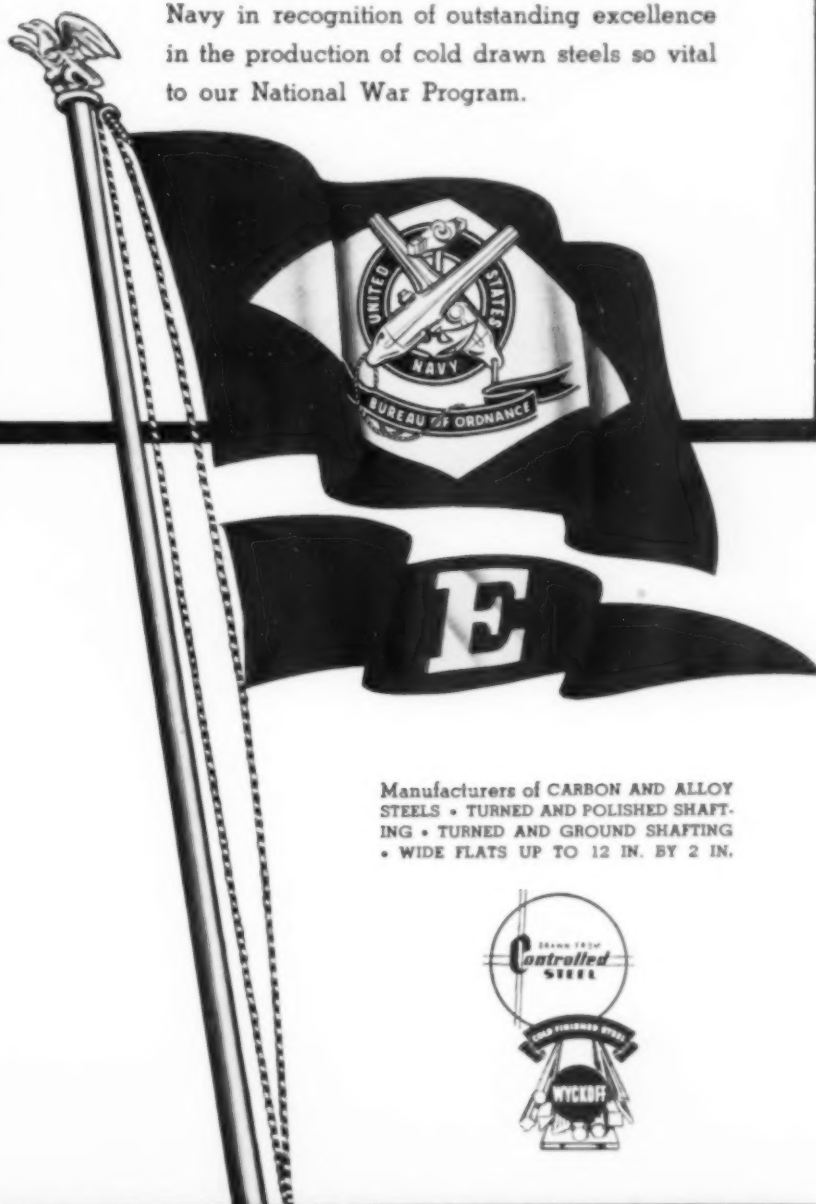
In a time when much of our steel is being used for construction, the valuable information contained in this book is particularly important and timely. Order your copy today.

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New Products Available

Readers may obtain complete details on these products by writing to METAL PROGRESS, and we will gladly pass the requests on to the manufacturer. Simply mention the paragraph numbers of the items in which you are interested.

Deep-Case Carburizing

Shown herewith is an immersed electrode salt bath furnace developed for a new operation known as "deep-case carburizing". This furnace is said to produce cases up to $\frac{1}{8}$ -in. depth, compared with former limitations of 0.050 in. Process is



applicable to tank gears, armor plates, splines, cams, transmission and other parts requiring heavily carburized cases for strength and wear. Furnaces are rated from 35 to 750 kilowatts power input, and have round or rectangular pots from 10 in. diameter to 20 ft. long, the latter size adaptable for deep-case carburizing large plate sections and long shafts. (No. 45)

Weld Spatter Eliminated

Weld spatter is eliminated with the use of a new product announced by Detroit manufacturer. By brushing, spraying or wiping this material along the edges of the metal surfaces to be joined by the weld, molten metal droplets fall off instead of adhering to areas adjacent to the seam.

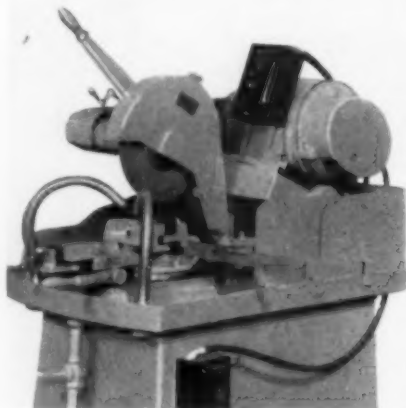
Subsequent grinding or scratching is not required and the seam is smoother—and stronger—because impurities are removed from the weld. Material is an excellent conductor of electricity and helps hold the arc. (No. 46)

Tracing Surface Finish

Newly designed "Mototrace", an accessory used with the profilometer for mechanical tracing of surface finish, has been announced. Mototrace is especially valuable for securing accurate readings on very fine surfaces. By its use, the profilometer tracer is drawn without vibration across the surface being measured. It is also useful for measuring softer materials, awkward shapes, distances as short as 0.03 in. and surfaces such as those in small holes, adjacent to shoulders or bosses, and on gear and hob teeth. (No. 47)

Wet Cut-Off Machine

Shown is new abrasive wet cut-off machine for accurately cutting bars, tubing and formed shapes. Coolant is directed onto the wheel and work at the point of contact and is said to increase



wheel life, reduce cutting heat and minimize any tendency to burn. (No. 48)

Oil Dermatitis Preventive

Industrial dermatitis or skin disorders caused by bacterial or fungus infestations in cutting oils, drawing oils, core oils and similar compounds is claimed to be prevented by addition of odorless, water soluble germicide in tablet form. Tablets are dissolved at the rate of one tablet per gallon of emulsified oil base or compound, and the solution is added to the cutting oil base before dilution. Tablets are dissolved in alcohol before adding to paraffin base oil. Samples available. (No. 49)

New Downstroke Friction Saws

To meet the demand for high speed friction saws for speed production of bombs, shells and bullets from solid or hollow, hot or cold steel stock, a Chicago engineering works announces a 36 and 48-in. downstroke friction saw with hydraulic feed and main motor sizes of 40 to 75 horsepower. High speed of rim, easy replacement of dulled tools, constant parallel plane of saw rotation, and elimination of end motion in swing frame are features. (No. 50)

Blackening Copper

New process called "Ebonol C", for simple, direct, low temperature, chemical blackening of copper and copper alloys, has been announced. Process involves immersion in a solution of blackening salts operated near the boiling point (200 to 212° F.) and is completed in from 2 to 10 min. depending upon the alloy being blackened. The coating is essentially cupric oxide, and being integral with the base metal, cannot chip or flake, it is said. It is hard enough to be buffed and does not have to be lacquered to prevent wear. Company will blacken samples. (No. 51)

TENUAL

• One of the first steps in producing aluminum castings is core making. This operation, in our foundry, is handled in every detail by experienced men under expert supervision using the latest type equipment. • All core sand is first mixed under scientific control for each individual case. Then all cores are carefully made, assembled and baked in the latest type thermostatically heat controlled ovens. After baking, the cores are carefully and accurately jigged, then placed in molds with assembly fixtures to insure dimensionally accurate castings. • These are just a few of the necessary steps that are expertly controlled to insure the high quality that has made National's Tenual Aluminum Castings famous.

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MAKE NATIONAL YOUR SOURCE OF SUPPLY

FOR SAND AND PERMANENT MOLD ALUMINUM CASTINGS



New Products Available

in addition to those shown on page 714

Rubber-Abrasive Polisher

Detroit firm announces a rubber-abrasive polisher, an accessory to a line of reciprocating action, portable, electric filing and honing tools. Polishers are rubber pads of various shapes

impregnated with abrasive and can be ordered in grits ranging from 80 up to 180. Advantages are for removing those last few thousandths and for production of mirror-like polished finish on dies and molds. (No. 52)



Stoker Main Shaft

—because . . .

- It increased production 66%!
- It multiplied tool life 3 times
- It saved \$20.73 per ton of steel used
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- It gave UNIFORM case hardening



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We're helping to "keep 'em rolling" with Speed Case Steel.*

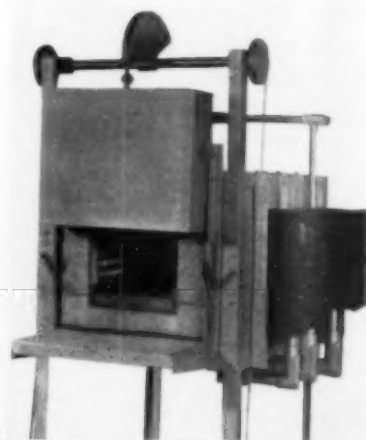
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MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

Electric Furnaces

New line of Falcon electric box type and muffle type furnaces include the one shown, with chamber 9 in. high, 12 in. wide and 36 in. deep, with a 16-kw. capacity suitable for 2000° F.



maximum operating temperature. Adaptable to factory and laboratory use for testing metal samples, heating high speed and similar steels in tool rooms, and for hardening and tempering.

(No. 53)

Marking Heat Treated Parts

New steel stamps with round face characters are designed for marking parts placed in torsional or tensile stress and where internal stresses of heat treated steel may concentrate at point of marking on surface. The rounded impression and special character design are said to provide the minimum stress.

(No. 54)

New High Speed Steel

New low tungsten-molybdenum steel known as TCM High-Speed Steel has been announced. No change in operating equipment is necessary when using the new steel because it is heat treated in the same furnaces and the same atmosphere as 18-4-1. Slightly lower hardening temperature contributes to a lower heat treating cost.

(No. 55)

See Note Top Page 714

NEED SKILLED HELP?

TO the man who is long on production problems and short on skilled technical help, we believe we can offer some assistance. For more than 25 years The Carborundum Company has been solving refractory problems for the metal industry. In the course of that time we've come up against pretty nearly every situation the business has to offer.

Our engineers are equipped with this background of experience to be particularly helpful to you today. They can quickly assist you in the proper selection and use of specialized refractories, saving you time and detail work.

Carborundum Brand Refractories include over 65 standard varieties in regular production, plus many special modifications. They are used to construct retorts, muffles, hearths, supports, or complete linings in all types of furnaces, including furnaces for forging, the reduction and refinement of non-ferrous metals, melting of non-ferrous and ferrous metals, reheating, tempering, hardening and carburizing.

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*Manufacture of Boron "Metal"

EXPERIMENTAL work directed toward eventual preparation of elemental boron has been in progress at the Electro-metallurgical Laboratories, Bureau of Mines, at Boulder City, Nev. This is a byproduct of a study of a large nearby deposit of colemanite ($2\text{CaO} \cdot 3\text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$),

once utilized as a commercial source of borax before the saline lake beds of California were developed. Boric acid can easily be separated from this roasted ore, even of low grade, since it goes into water solution if CO_2 is bubbled through. Likewise boric acid is a "natural" floating

material; 90% acid can be separated in a standard flotation cell without any reagent whatever.

Intermediate products prepared from colemanite mineral for eventual conversion to metallic boron include calcium boride, CaB_6 . The compound has certain commercial uses in its own right, such as a deoxidizer for non-ferrous alloys and as a source of boron for the preparation of other borides and alloys of boron. Preparation of CaB_6 electrolytically was described in 1940 by Messrs. KOSTER, KNICKERBOCKER and Fox of the Bureau of Mines staff.

Calcium boride as an intermediate source for metallic boron through interaction with boron trichloride proved unsatisfactory. Magnesium boride showed greater promise of success, but its preparation by electrolysis of fused oxides and fluorides proved unsuccessful, and anhydrous magnesium chloride became an essential constituent for the work. This fused salt was electrolyzed at approximately 900°C . (1650°F .) in a bath containing 1-10 parts by weight of MgO , B_2O_3 , and MgCl_2 . However, the cathodic product proved unstable when excess salt was leached from the boride.

An alternative method for making magnesium boride is the thermit reaction between powdered magnesium and boric oxide, carried out in magnesium crucibles under an inert atmosphere of helium. A series of trials shows that equal parts of magnesium powder and boric oxide yield over 95% magnesium boride when the reaction is started at 1050°C . (1925°F .)

To obtain boron metal the boride must be decomposed and magnesium removed. This was done by heating to 750°C . (1375°F .) in the presence of BCl_3 under pressure of 115 psi. The reaction was carried out in closed system, a copper boat being the container, and the product was slightly contaminated with copper, analyzing 93.2% B, 1.0% Mg and 0.8% Cu.

*Notes from Annual Report of Metallurgical Division, Bureau of Mines; Fiscal Year 1941.

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Dempsey Furnaces in leading shipyard.



IN THE
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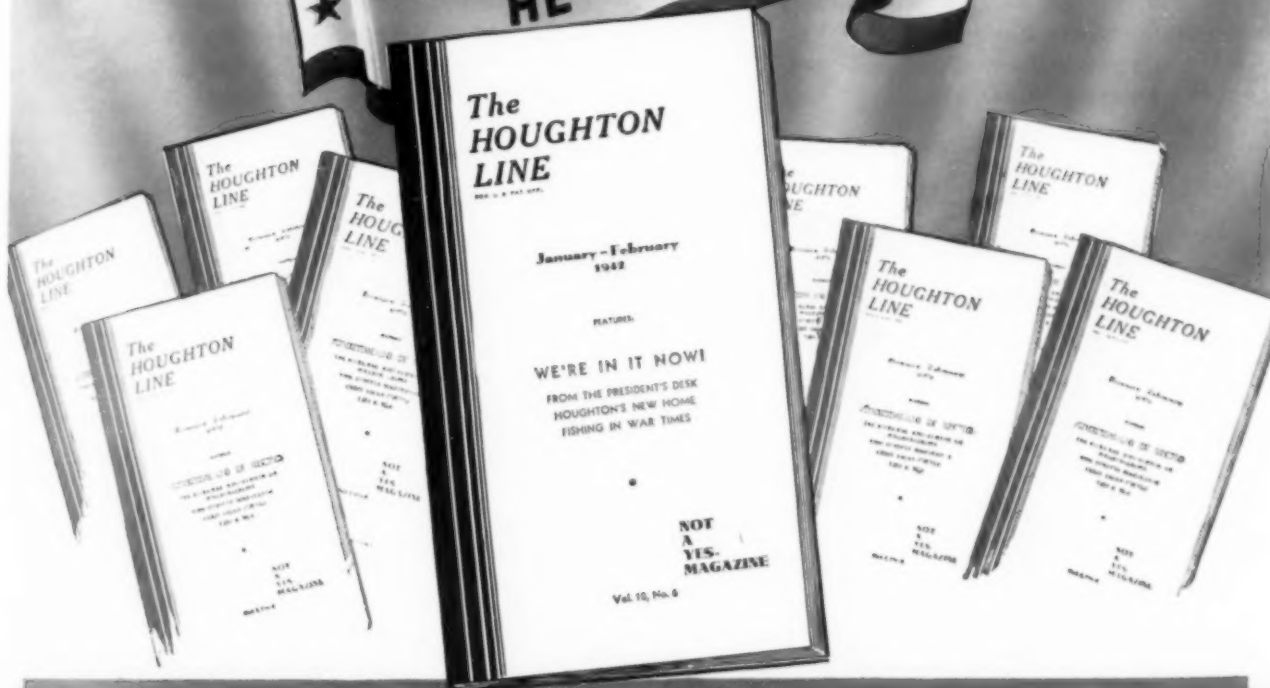
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HE CAN GET!*



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As industry changes over from peace-time to war production, plant men face many new problems—machining new steels or new metals... cleaning, heat treating, quenching, preventing rust, special lubrication. These problems are covered regularly in the "Houghton Line," which for 34 years has been sent to industrial plant executives the world over.

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MP

Furnaces

(Continued from page 662)

are pre-mixed and reacted ("burned"), sometimes in the presence of a catalyst. Usually the flue gases are cooled to condense most of the water vapor; for some purposes the gases are dried much more thoroughly. A typical analysis chart (Fig. 9,

page 662) gives the composition obtained from such a generator that will operate without additional external heat.

For perfect combustion of air and natural gas, for instance, CO_2 is at a maximum of approximately 12%, the actual value depending on the composition and specific gravity of the natural gas used. As the proportion of gas in the pre-mixed combustibles increases, the CO_2 decreases

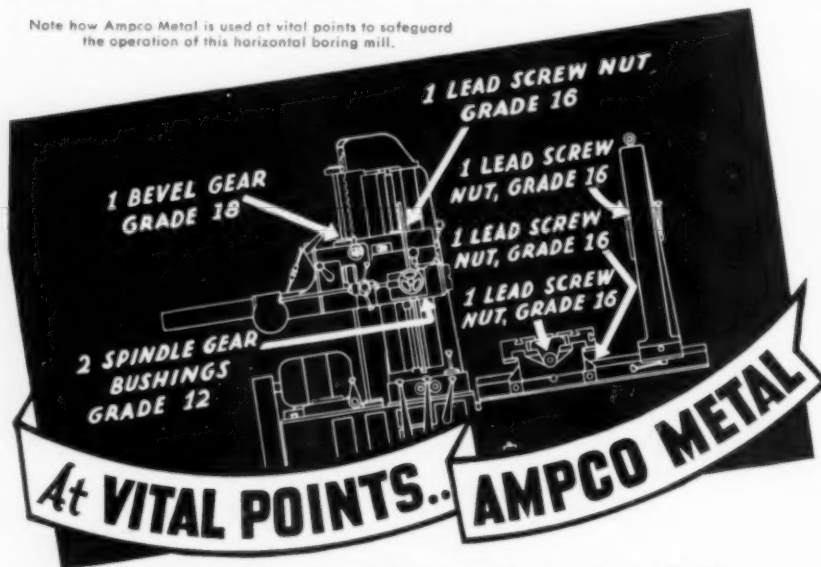
and the CO and H_2 increase. The limiting ratio for operating such generators is about five parts air to one part of gas, giving an analysis approximately as shown on the left side of the curves.

For the sintering of copper and many of its usual alloys any reducing atmosphere up to perfect combustion will be satisfactory, providing no free oxygen is present. A flue gas safely on the "reducing" side is usually used, as it is more economical than a richer one.

Sintering of other metals requires other atmospheres. Pure iron will oxidize in an atmosphere suitable for copper, both because of the CO_2 and the water vapor present. An atmosphere must be provided in which the water vapor is removed to a safe limit and a suitable $\text{CO}:\text{CO}_2$ ratio is maintained. A ratio of 6:1 between air and natural gas will give an atmosphere with approximately 10% CO and 5% CO_2 ; such an atmosphere dried to a dew point of 40°F . is satisfactory for sintering iron at 2000°F .

Conclusion—In this discussion there have been presented some of the problems involved in the commercial large-scale production by powder metallurgy of parts such as porous metal bearings made from copper and tin powders (and other parts made from iron powder) with particular reference to the sintering operation. An attempt has been made to distinguish the effects of variables in the materials and processing which originate before sintering from the effects which can originate during the sintering operation. Finally, a furnace has been described, designed so that the physical properties and dimensional change of parts sintered in it can be controlled within certain limits. It must be remembered that the results are only for the conditions under which the sintering was done, and that other values may be obtained when other conditions exist.

Note how Ampco Metal is used at vital points to safeguard the operation of this horizontal boring mill.



3 to 5 Times More Service Life

Customer satisfaction—continuous production—depend upon the smooth functioning of all parts of the machine. Vital parts subject to friction and wear must give long life—must stand up and "take it" under severe operating conditions.

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Ampco Metal is made in six alloy variations, suiting it for a wide range of service applications. Physical properties are uniformly high. It is essentially a bronze for the tough jobs—where other metals fail. Usually Ampco gives from three to five times more service than ordinary bronzes.

Ask for Literature

The panel to the left contains a list of literature available describing Ampco Metal as used in varied applications. Ask for those bulletins that meet your needs.

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AMPCO LITERATURE Available

AMPCO METAL, catalogue 22
Ampcoloy—Industrial Bronzes
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Ampco-Trode Coated Aluminum
Bronze Welding Rod
Ampco Metal in Machine Tools
Ampco Metal in Bushings and
Bearings
Ampco Metal in Dies
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AHEAD OF SCHEDULE

Metallurgists say:

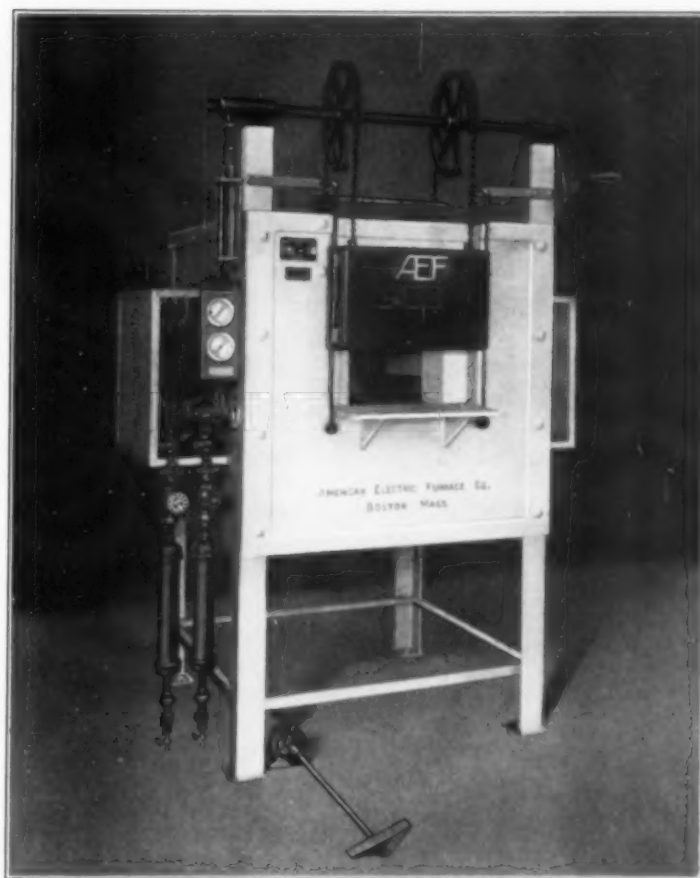
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Resulting from the use of
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high. Rating 33 K.W.



American Electric Furnace Company

30 VON HILLERN ST.



BOSTON, MASS., U. S. A.

Industrial Furnaces for All Purposes

Openhearth

(Continued from page 679)

identified. Proper identification would allow it to be charged when making steels that would not be injured by 0.10 or 0.15% tin, but bundles are often received with the tin scrap hidden in the center, and proper segregation is difficult or impossible. Bundles of this type should certainly be

rejected by all buyers in order to enforce the proper identification and segregation of the tinned scrap.

Salvaging of old automobiles was thoroughly discussed. This problem is more complicated than is generally realized. The original investment in even a used car is usually many times its value as actual scrap, and the labor necessary to demolish and to properly separate the various

materials is also considerable. To further muddy the picture, it was pointed out that the "graveyards" were the source of spare parts necessary to keep a great many autos of our war workers in running order. In spite of the above conditions, industry is recovering and converting thousands of old machines into prime steel each month.

Furnace Construction—Probably the outstanding trend in furnace construction is in the installation of new bottoms of rammed materials. In place of the older practice of burning-in all the bottom from the brickwork up, we see an increasing portion of the bottom being rammed in with prepared material and a thin coating of magnesite burnt-in in the conventional manner for the top or working surface. Many of the newer furnaces have as little as 3 in. of magnesite burnt in. This practice speeds up furnace construction; results are reported to be as satisfactory, so far as delays are concerned, as the conventional bottoms.

Several quick setting materials were described for use in repairing large bottom holes. Operators gave numerous results of experiences where large holes had been cleaned out, shoveled full of a quick setting material, covered with an inch or two of magnesite or dolomite, and the furnace charged almost immediately. In no case had the quick setting materials failed to hold.

The supply of magnesite for furnace construction and maintenance appeared to be assured, but the position of refractory chrome ore was less positive. Cuban ore, if properly sized and prepared with suitable binders, was felt to be satisfactory for substitution of ore from better known sources in far distant lands. Adding some magnesite to the chrome ore was reported to have produced good results. Olivine is another material that

(Continued on page 736)



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R-S Heat-Treating Furnaces have been developed for victory production needs and high peaks of efficiency in automatic operation.

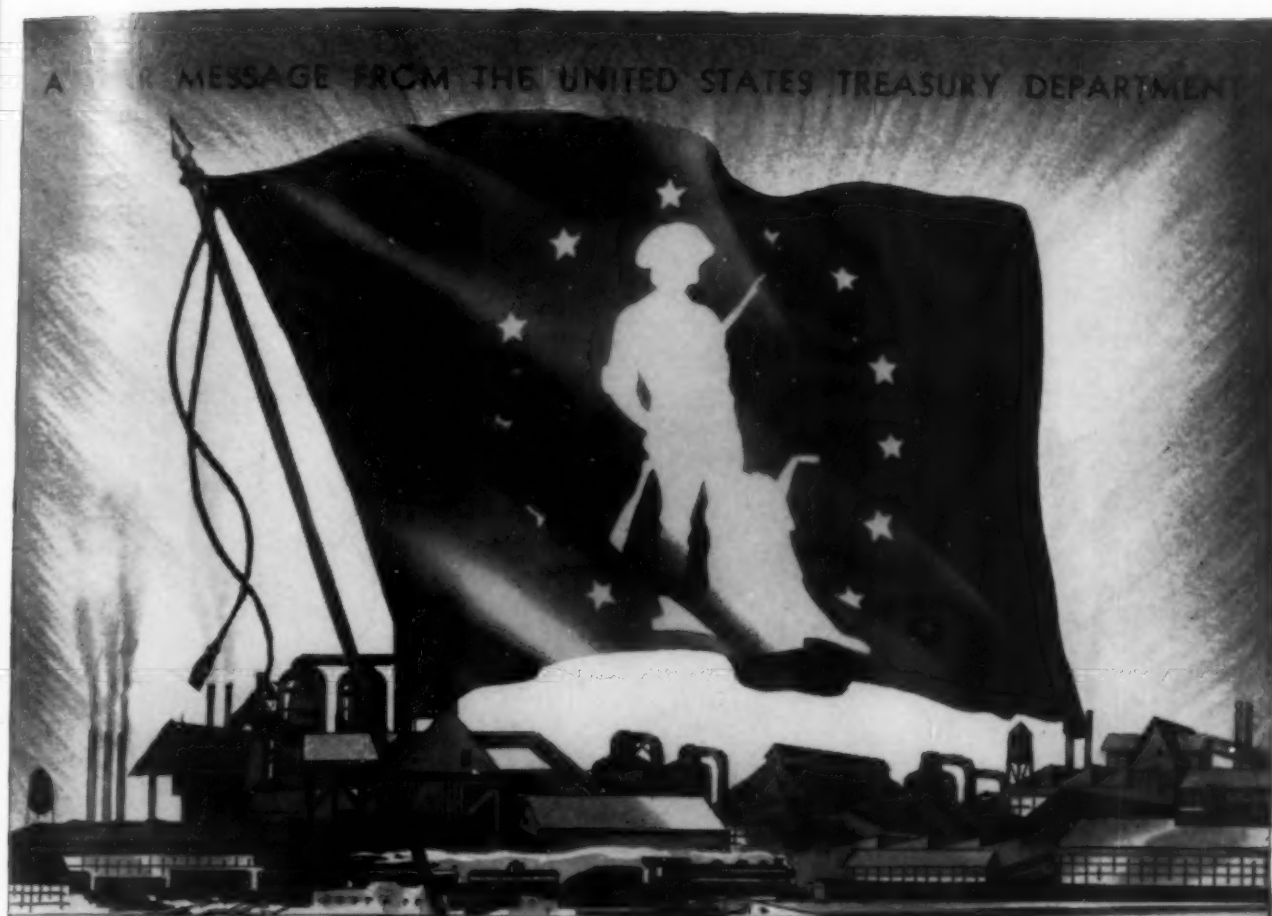
In recent months, new methods of automatic control have been applied to mechanical apparatus and material handling equipment. Reception has been enthusiastic. Such favorable results have been obtained that numerous repeat orders have resulted.

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It doesn't go into the smoke of battle, but wherever you see this flag you know that it spells Victory for our boys on the fighting fronts. To everyone, it means that the firm which flies it has attained 90 percent or more employee participation in the Pay-Roll Savings Plan . . . that their employees are turning a part of their earnings into tanks and planes and guns *regularly*, every pay day, through the systematic purchase of U. S. War Bonds.

You don't need to be engaged in war production activity to fly this flag. Any patriotic firm can qualify and make a vital contribution to Victory by making the Pay-Roll Savings Plan available to its employees, and by securing 90 percent or more employee participation. Then notify your State Defense Savings Staff Administrator that

you have reached the goal. He will tell you how you may obtain your flag.

If your firm has already installed the Pay-Roll Savings Plan, now is the time to increase your efforts: (1) To secure wider participation and reach the 90-percent goal; (2) to encourage employees to increase their allotments until 10 percent or more of your gross pay roll is subscribed for Bonds. "Token" allotments will not win this war any more than "token" resistance will keep our enemies from our shores, our homes. If your firm has yet to install the Plan, remember, **TIME IS SHORT.**

Write or wire for full facts and literature on installing your Pay-Roll Savings Plan now. Address Treasury Department, Section D, 709 12th St., NW., Washington, D. C.

Make Every Pay Day "Bond Day"



U. S. **WAR Bonds ★ Stamps**

Openhearth

(Starts on page 676)

should be carefully studied for use in furnace maintenance, either used as straight olivine or mixed with chrome ore.

Suspended checker roofs were credited with good results as to life and increased preheat of the air (due to the larger heating surfaces made available by this

type of construction). The larger initial cost of the suspended roof over the sprung arch type was believed justified in most cases.

Furnace construction has been studied with a view of eliminating the usual slow-down during the latter part of the campaign. Checkers are periodically blown and a series of jets are built below the rider walls and in the flues so that material accumulating in these sections can be blown

out the stack. The jets are operated with steam and are enclosed by brickwork. They last for several campaigns.

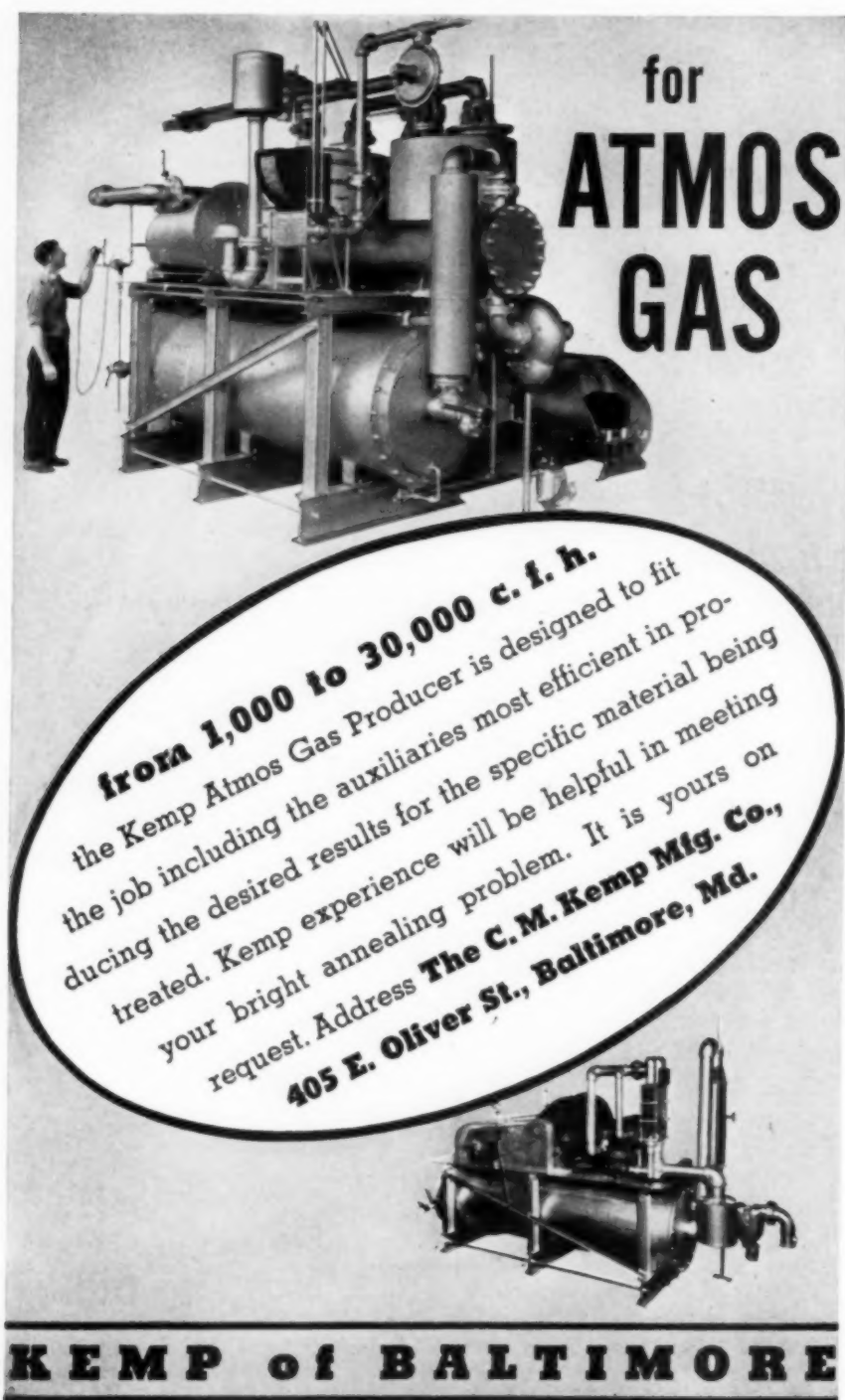
Furnace doors, studded and then rammed with a quick setting refractory, were giving excellent results throughout the openhearth industry. Various types of studs were used such as straight rods, bolts, and railroad spikes. Frames were also protected in the same manner.

Instruments — New types of instruments are proving beneficial, both as to cost and speed of results. The spectrograph is being used in numerous shops for preliminary and final analysis on various elements. Nickel, tin, chromium, copper and molybdenum were elements mentioned as suitable for spectrographic analysis. Other alloys are being investigated.

The "photometer" was reported as practical for the analysis of nickel, chromium, molybdenum, phosphorus and nitrogen.

The "Leco Machine" has given certain plants excellent and speedy determinations for carbon and sulphur. One plant reports carbon checks in 9 to 12 min., using the thimble method for obtaining the steel sample. The steel thimble is crushed in a mortar if the steel is above 0.18% C. If the carbon is lower, the sample is prepared by clipping it with shears to the desired size. The machine has a definite place in shops where alloys in the steel may interfere with the use of a carbometer.

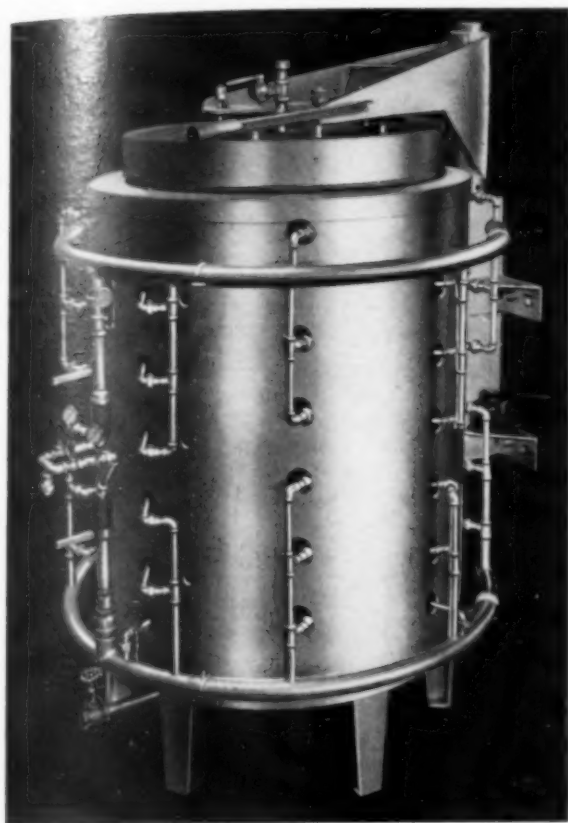
Roof temperature control was felt to be satisfactory in most cases both in regards to protecting the roof and in saving fuel. Some plants have varied the procedure somewhat by taking temperatures through carbon blocks in the furnace roof or at the uptakes or fantails. The latter location detects unburnt fuel as it enters the checkers and has proven advantageous from this standpoint.



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GAS**

from 1,000 to 30,000 c. f. h.
the Kemp Atmos Gas Producer is designed to fit the job including the auxiliaries most efficient in producing the desired results for the specific material being treated. Kemp experience will be helpful in meeting your bright annealing problem. It is yours on request. Address **The C. M. Kemp Mfg. Co., 405 E. Oliver St., Baltimore, Md.**

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The retort is a heavy wall casting guaranteed for 5000 hours, normal expectancy 7500 hours.

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The retort seal can be inspected 100% before the outer cover is completely closed.

Our usual rugged construction is maintained throughout.

These features, combined with the uniform results, low operating and maintenance costs regularly being obtained, are worth investigating.

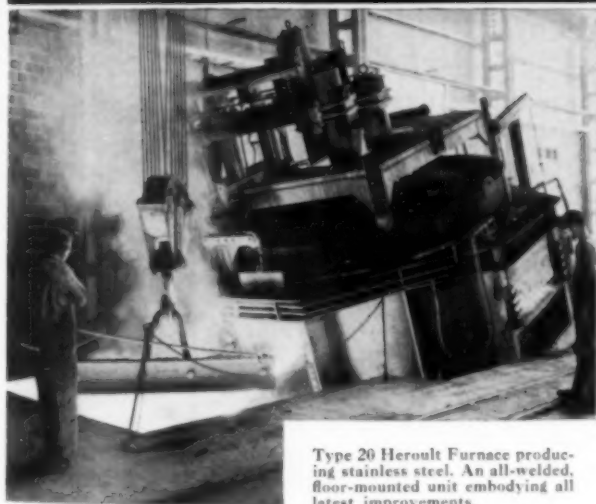
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Type 20 Heroult Furnace producing stainless steel. An all-welded, floor-mounted unit embodying all latest improvements.

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METAL AND THERMIT CORPORATION

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Inclusions

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Since it is a question of a crystalline effect, the crystalline system and consequently the nature of the inclusion might be considered. A typical example, important because of its industrial consequences, is given by graphitization of cementite in the

solid state, a fundamental phenomenon in the manufacture of malleable iron. On annealing white iron for graphitization, the graphite appears in masses or nodules surrounding inclusions which form nuclei. If the inclusion is of iron sulphide crystallizing in the hexagonal system, it produces a radiating or spherulitic aggregate of oriented crystals; if on the other hand, the inclusion is of manganese sul-

phide in the cubic system, it produces an aggregate of dispersed or unoriented lamellae. Thus the crystalline system of the inclusion determines the structural form of the nodules of graphite, and consequently affects, to that extent, the mechanical properties of the malleable iron obtained. Since the nature of the inclusions depends on the melting and refining of the metal and on the final additions, we can see how these factors can act directly, through the inclusions, on the properties of the solid product.

In summary, the additions made to molten steel at the end of the refining period can affect its properties in various ways; they can modify directly the composition and structure of the metallic part of the alloy, or they can act indirectly through the agency of the non-metallic portion of the body—that is to say, the inclusions.

This influence on the inclusions (and hence on the properties) can likewise be either direct or indirect.

When it is direct it might consist simply in a modification of the nature, the form and the distribution of the inclusions. Thus the malleability of a metal can be changed by transforming the inclusions existing as intergranular films into rounded and disseminated ones (for example, the effect of magnesium on the malleability of nickel containing sulphur as an impurity). Likewise certain properties of a steel can be changed by the transformation of silicate inclusions into alumina by a proper addition of aluminum.

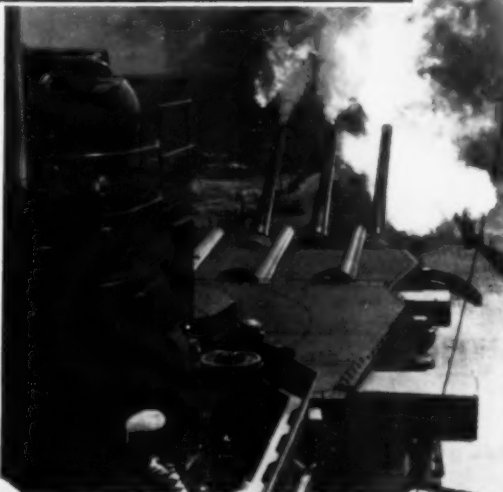
However, as has been shown here, the influence of inclusions can also be indirect, by a modification of the structure surrounding the precipitated constituents, since the inclusions act as a germ for the start of crystallization.

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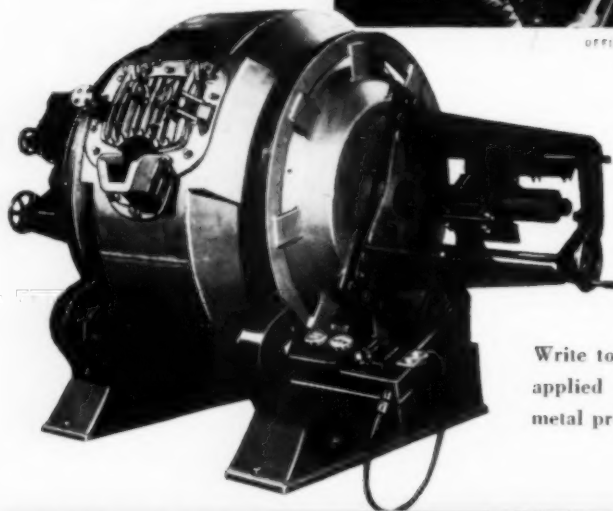
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